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Coast Guard Mission Data Recorder (MDR) for the 47-FT Motor Lifeboat - Phase 3

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16. Abstract

Mission Data Recorders (MDRs) were designed and built by the Coast Guard Research and Development Center to autonomously collect quantitative motions data on the 47-FT preproduction Motor Lifeboats (MLBs) over a long period of time. The purpose of the MDR was to collect both short-term event data and long-term vessel motions data in an autonomous manner, similar to an aircraft flight recorder. Phase 1 results were published in Report No. CG-D-20-94 which contains detailed descriptions of the MDR development and analysis of significant roll events recorded during the period of October 1993 to June 1994. Phase 2 results were published in Report No. CG-D-17-95 which contains follow-up discussions with coxswains of boats that experienced significant events, the development of engine usage profiles, and analysis of additional significant events from the period of June 1994 to March 1995.

Phase 3 results present a final compilation of MDR statistics data that have been collected for more than two years and includes the time period from March 1995 through April 1996. A total of 10 significant roll events, hundreds of hours of tracking the locations of the MLBs, and hundreds of underway hours of motion statistics and engine usage have been captured and analzyed. This represents the most comprehensive database of underway information ever collected on a Coast Guard MLB. These data were used to construct engine usage profiles, and roll, pitch and heave acceleration frequency distribution curves.

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METRIC CONVERSION FACTORS

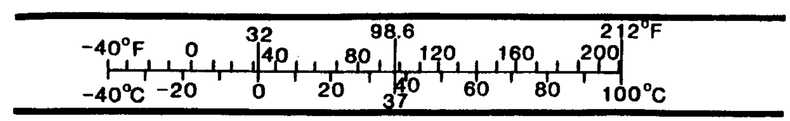
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (WEIGHT)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (EXACT)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly).

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (WEIGHT)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	0.125	cups	c
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (EXACT)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



EXECUTIVE SUMMARY

Mission Data Recorders (MDRs) were designed and built by the Coast Guard R&D Center to autonomously collect quantitative motions data on the 47-FT preproduction Motor Lifeboats (MLBs) over a long period of time. The purpose of the MDR was to collect both short-term event data and long term vessel motions data in an autonomous manner, similar to an aircraft flight recorder. Phase 1 results were published in Report No. CG-D-2-94 which contains detailed descriptions of the MDR development and analysis of significant roll events recorded during the period of October 1993 to June 1994. Phase 2 results were published in Report No. CG-D-17-95 which contains follow-up discussions with coxswains of boats that experienced significant events, the development of engine usage profiles, and analysis of additional significant events from the period of June 1994 to March 1995.

Phase 3 results presents a final compilation of MDR statistics data that has been collected for more than two years and includes the time period from March 1995 through April 1996. The MDRs have been removed from the 47-FT preproduction MLBs. A total of 10 significant roll events, hundreds of hours of tracking the locations of the MLBs, and hundreds of underway hours of motion statistics and engine usage have been captured and analyzed. This represents the most comprehensive database of underway information ever collected on a Coast Guard MLB. These data were used to construct engine usage profiles, and roll, pitch, and heave acceleration frequency distribution curves. These curves can be used to predict the number of hours a particular boat or all the boats might experience a specified peak acceleration, roll, or pitch and also what the composite profile of engine usage is for all of the boats.

ACKNOWLEDGMENTS

The cooperation of each of the five small boat stations, Cape May, Oregon Inlet, Tillamook, Umpqua River, and Gloucester tasked with testing the preproduction 47-FT Motor Lifeboats is gratefully acknowledged. Appreciation is also expressed to Station Cape Disappointment and the National Motor Lifeboat School for their assistance in coordinating the installation of the MDR on the 47200 prototype.

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1 Introduction

The 47-FT Motor Lifeboat (MLB) design was developed by the U.S. Coast Guard and Textron Marine Systems. The 47-FT MLB is designed as a heavy weather rescue boat with self-righting capabilities. The self-righting capability of a 47-FT MLB is essential since it can be expected to encounter violent motions in the surf with an occasional severe roll or even 360 degree rollovers in the course of conducting operations.

The Coast Guard is in the process of replacing the aging 44-FT MLBs with the 47-FT MLBs. Five preproduction boats underwent an Operational Test & Evaluation (OT&E). The five Coast Guard small boat stations involved with the OT&E were:

Station Cape May, Cape May, NJ	47201
Station Oregon Inlet, Rodanthe, NC	47202
Station Tillamook, Garibldi, OR	47203
Station Umpqua River, Reedsport, OR	47204
Station Gloucester, Gloucester, MA	47205

The objective of the OT&E as defined in the OT&E Plan in Reference [1] was to evaluate the *effectiveness* and *suitability* of the Coast Guard 47-FT MLB. The results of the OT&E were presented to the Coast Guard Acquisition Review Council (CGARC) in Reference [2].

The R&D Center was tasked to develop a Mission Data Recorder (MDR) to autonomously record operating hours, motion environment, operational profile, and capture any significant events such as a boat rollover. The task of developing the MDR, which addressed one of the six OT&E evaluation components in Reference [1], was presented in Reference [3].

2 Background

2.1 Mission Data Recorder Objectives

Two main objectives were established from the start of this project to collect motions data on the 47-FT MLB. They were as follows:

- The primary objective for the MDR was to have the ability to reconstruct a severe dynamic event such as a rollover when an established threshold is exceeded.
- The secondary objective for the MDR was to collect data to develop motion and underway time histories.

These objectives applied to all three phases of MDR data collection, Phase 1, Phase 2, and Phase 3. The MDRs were physically aboard the 47-FT MLBs between the following dates:

MDR Installation Date	MDR Removal Date
47201 - 30 Sep. 1993	47201 - 12 Jun. 1996
47202 - 29 Oct. 1993	47202 - 22 Apr. 1996
47203 - 18 Nov.1993	47203 - 24 Apr. 1996
47204 - 24 Jan. 1994	not removed
47205 - 3 Feb. 1994	47205 - 17 Jun. 1996
47200 - 16 May 1994	47200 - 23 Apr. 1996

It must be noted that there was a boat switch between Station Umpqua River and the National Motor Lifeboat School. The school acquired the 47204 sometime in January of 1996 because it was considered more representative of the boats that its students would use in operations. There have been gaps in MDR data coverage when the boat was disconnected from shore-tie power for more than several days, e.g., boat repairs or crew neglecting to check MDR status, which would have caused a complete power drain and memory purge on the MDR. No data have been collected on the 47200 because of the frequent times it spent out of the water for overhaul work. In general, the coverage has been good on the preproduction MLBs, considering the length of time that the MDRs were aboard and that only one significant event was not captured.

2.2 MDR Functional Overview

The MDR was developed to function like an aircraft flight recorder 'black box." The concept was to use a self-contained sensor package and data-logger to record the motions and control settings on the 47-FT MLB when threshold conditions were exceeded. The recorded data would be played back after an incident to help reconstruct the actual event. The MDR collects the information illustrated below.

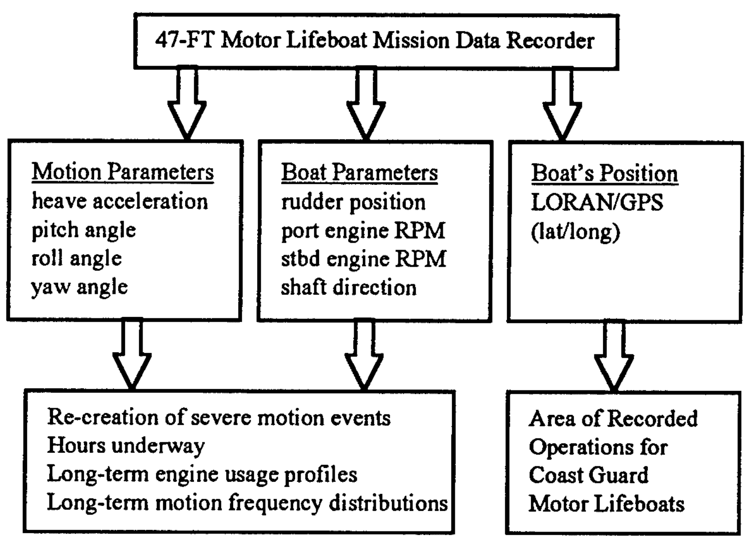


Figure 1 Information Collected by the Mission Data Recorder

The MDR was designed to operate autonomously with minimal crew participation. The MDR remains in a low power "stand-by-mode" and charges up its battery when the 47-FT MLB is on shore tie. After a relay detects a shore-tie disconnect, it turns on and begins data collection. This enables the MDR to monitor the boat's motions from the moment it leaves the dock until it returns. After the shore-tie is reconnected, the MDR resumes its low power "stand-by-mode" and charges up its battery for the next mission. A detail description of the MDR sensors, data-logger, software, and operations can be found in Reference [3]. In addition to the set of 12 minute events that can be captured with the MDR, statistical averages are collected every 10 minutes the 47-FT MLB is underway. The data in a 10 minute buffer are statistically reduced before the buffer is overwritten in the case of a non-event, saving the following:

- date and time
- heave RMS, heave average, highest heave value detected, lowest heave value detected
- pitch RMS, pitch average, highest pitch value detected, lowest pitch value detected
- roll RMS, roll average, highest roll value detected, lowest roll value detected
- average port shaft RPM
- ship's position (lat/long)

Figures 2 and 3 are plot keys presented from Reference [3] that demonstrate snapshots of how the animation data were provided for events captured. Figure 4 is a plot key presented form Reference [3] that provides an interpretation to the Area of Recorded Operation (ARO) plots that are presented in this report.

Initially the re-creation of significant events was the focus of the data collected by the MDR. However, with the collection of statistics over a long period of time, i.e., hundreds of MDR recorded underway hours, the reduction of the statistics has become more meaningful.

2.3 Summary of Phase 1 Results

Phase 1 data collection took place from October 1993 through June 1994 in support of the first six months of the OT&E period. The initiation of the MDR data collection was staggered between the MLBs because of the preproduction delivery schedule. The 47201 MDR collection began in October 1993 whereas the last boat delivered, 47205, began MDR data collection in February 1994. A total of nine significant events were recorded. The MDR roll threshold settings ranged from 30 to 45 degrees. A few exceptional events were recorded including a 137 degree roll on the 47202, a combination 53 degree roll and 35 degree pitch event on the 47201, and a 72 degree roll experienced by the 47203. On two occasions where a severe roll occurred, the engine on the side toward the roll stalled and was restarted in about one-minute. The stalling of the engine after one of the events on the 47201 was a result of splitting of the throttles (i.e., quickly shifting one engine in reverse, at high speed to improve turning maneuverability). The 47201 went up the back of a 12 foot swell, crested the swell, and rapidly accelerated down the face of it as the boat turned left and came abeam to the swell. The 47201 quickly rolled to starboard 53 degrees and also pitched to 35 degrees. The starboard engine stalled after the coxswain moved the

starboard throttle past reverse. It took 53 seconds to bring the starboard engine back on line. The second instance of a stalled engine after a roll occurred on the 47202 after a 137 degree roll. However, it is not known why the engine stalled in this instance. Neither engine was throttled through reverse but maintained RPM levels below clutch speed. The events are analyzed and discussed in detail in Reference [3]. Reverification testing documented in Reference [5] was performed by the R&D Center on the 47201 after engine replacement with the Detroit Diesel Electronic Control (DDEC) and after a DDEC TECHEVAL was performed as documented in Reference [6]. Testing performed with the new engines revealed that the inboard engine would also stall in 20 knot split-throttle turning maneuvers in calm water.

A computer animation capability, BOATVU, was developed in Phase 1 which assisted in debriefing the crew on the captured events. BOATVU uses a 3D wire frame rendition of the 47-FT MLB to recreate the significant event by importing the motion time series information from the MDR. BOATVU animations for the events in Phase 1 are presented in Reference [3].

Areas of Recorded Operations (AROs) were developed for each station using the Coast Guard Electronic Engineering Center's program, Geographical Display Operations Computer (GDOC). Motion statistics collected in Phase 1 were reduced and presented on a monthly basis.

In Reference [2], the Office of Search and Rescue (G-OCS) recommended proceeding with the production phase of the 47-FT MLB Acquisition Project while continuing to evaluate the MLBs in heavy weather and surf operations. Therefore, the MDRs remained aboard the preproduction MLBs for an extended period.

2.4 Summary of Phase 2 Results

The Phase 2 data collection period was from June 1994 through March 1995. The MDR roll thresholds were set to 60 degrees on all of the boats except the 47202. A single event was captured in Phase 2 on the 47202 which had its roll threshold set lower than intended. The event that triggered the 47202's MDR was from sharp starboard rolls associated with the 47202 pulling a 74-FT fishing vessel off of a sand bar. This event was analyzed in detail in the Phase 2 report in Reference [4]. Because the MDRs remained aboard longer, more motion and engine RPM statistics were captured. Engine usage profiles, heave frequency distributions, and roll frequency distributions were developed for each MLB.

3 Discussion

3.1 47-FT MLB Motion Statistics Analysis

No significant events were recorded by the MDR in Phase 3. There was one instance of a significant event that was missed on the 47204 at Station Umpqua River. According to the station, their boat experienced a roll in excess of 60 degrees. Unfortunately, the station

had neglected to perform the routine check of the MDR power status light and the 47204 MDR experienced a complete power drain and had shut down sometime before the event.

Even though no events were captured in Phase 3, the MDR continued to collect more statistics data. The MDRs collected thousands of hours of data as shown below:

- 47201 - 2,446 hours MDR operation
- 47202 - 1,769 hours MDR operation
- 47203 - 1,444 hours MDR operation
- 47204 - 1,906 hours MDR operation
- 47205 - 2,522 hours MDR operation

However, much of this data, before any sorting was performed, represents a significant amount of time in the boat's slip when the shore-tie would be disconnected for various reasons such as daily preventive maintenance checks (PMS) checks. The emphasis of this report addresses the reduction of some of the statistics. For the roll, pitch, and heave data, only the highest recorded values in each 10 minute period were used in the following analysis and discussion. The analysis approach was to perform a frequency sort to compute the numbers and proportions of observations falling into specific ranges for roll, pitch, heave, and RPM values considered.

Roll Frequency Distributions:

The roll frequency distributions were developed by sorting observed high roll values into 2 degree ranges (or bins) starting at a lower bound of 0 degrees to an upper bound of 30 degrees. Only roll data associated with engine RPM greater than 200 RPM were included. Sorting the roll information this way assured that only underway motions were considered in the analysis. Therefore, motions associated with the boat docked in its slip were excluded. This approach is considered better than the sorting approach used in Reference [4] which excluded all roll data less than 2 degrees. The approach used in this report is more representative of the peak roll distribution encountered whenever the MLBs are underway.

The roll frequency distribution data presented in Table 1 represent the summary of high roll values captured over a time frame of over two years or hundreds of underway hours on the preproduction 47-FT MLBs.

Table 1 Preproduction 47-FT MLB Roll Frequency Distribution

Roll (degrees)	47201 (%occurrence out of 495 hrs)	47203 (%occurrence out of 531 hrs)	47205 (%occurrence out of 825 hrs)	47204 (%occurrence out of 658 hrs)	47202 (%occurrence out of 731 hrs)
0-2	50.59	57.83	53.5	48.48	67.05
2-4	15.73	12.65	16.11	15.41	12.37
4-6	11.75	11.37	11.03	12.72	7.69
6-8	10.27	10.02	9.7	11.66	6.89
8-10	4.82	3.83	4.57	5.58	2.81
10-12	3.03	2.14	2.79	2.33	1.51
12-14	2.16	1.16	1.32	2.00	0.8
14-16	0.54	0.5	0.49	0.66	0.39
16-18	0.54	0.16	0.18	0.61	0.25
18-20	0.34	0.25	0.22	0.33	0.09
20-22	0.1	0.03	0.02	0.15	0.07
22-24	0.1	0.06	0.04	0.05	0.09
24-26	0.03	0	0.02	0.03	0

The roll frequency distribution curves for each preproduction MLB are presented in Figures 5 through 9. As an example of how the curves can be used, it is apparent from Figures 5 through 9 that the MLBs will experience 16-18 degree peak rolls less than one percent of the time while underway. The results between the boats could be averaged to generate a composite picture of peak roll motions that can be expected in service on the production MLBs.

Pitch Frequency Distributions:

Tables 2 and 3 present the pitch frequency distributions for the 47-FT MLBs. The pitch frequency distribution is broken down into two tables, one for when the bow is up (denoted by negative pitch readings) and one for when the bow is down (denoted by positive readings). The pitch data in Table 2 were sorted from -85 to 0 degrees in 5 degree bins for associated engine RPM readings greater than 200 RPM. The pitch data for Table 2 are presented as bar graphs for each MLB in Figures 10 through 14. Based on the sort method, it appears that all of the MLBs will experience bow up pitch peaks of 20 to 25 degrees less than one percent of the time they get underway. The 47203 experienced higher pitch peak encounters than the other MLBs. The 47203 experienced pitch angles between 65 and 70 degrees 2.29 percent of the time they got underway. A discussion with the XO at Station Tillamook revealed that they felt that they had encountered those kinds of angles in some surf operations.

Although the roll and pitch sensors are the same, their application is different. The pitch sensor in its orientation would be more affected by boat slamming. Some of the readings in the 10ths and 100ths of percent occurrence, e.g., 0.03% occurrence of 80 to 85 degree pitch angles for the 47203, for pitch values above 45 degrees may be artifacts of the sensor. The pitch sensors are fluid-filled electronic pendulums. Small transients of pitch

could occur under severe slamming and even more severe transients could occur when the boat's pitch frequency approaches the sensor's natural frequency around 3 Hz.

The bow down pitch results are not plotted because severe bow down angles are less likely to occur. They occasionally occur when riding down the face of a wave. However, it is expected that the MLBs would have taken every precaution to avoid any steep inclines down the face of a wave since this could lead to a very unsafe situation. It is apparent from Table 3 that the MLBs have experienced bow down pitch angles of 6-8 degrees less than about one percent of the time they were underway.

Table 2 Preproduction 47-FT MLB Pitch (Bow Up) Frequency Distribution

Pitch (degrees)	47201 (%occurrence out of 495 hrs)	47203 (%occurrence out of 531 hrs)	47205 (%occurrence out of 825 hrs)	47204 (%occurrence out of 658 hrs)	47202 (%occurrence out of 731 hrs)
-85 - -80	0	0.03	0	0	0
-80 - -75	0	0	0.02	0	0
-75 - -70	0	0.28	0.34	0	0
-70 - -65	0	2.29	0	0	0
-65 - -60	0	0.28	0.02	0	0
-60 - -55	0	0.22	0.02	0	0
-55 - -50	0	0.16	0	0	0
-50 - -45	0	0.09	0	0.05	0
-45 - -40	0.2	0.06	0.04	0.03	0.07
-40 - -35	0.39	0.19	0.12	0	0.05
-35 - -30	0.1	0.13	0.18	0.1	0.14
-30 - -25	0.44	0.22	0.28	0.26	0.11
-25 - -20	0.54	0.85	0.69	0.39	0.52
-20 - -15	1.08	2.51	1.15	1.34	1.6
-15 - -10	3.33	13.47	7.78	6.79	13.89
-10 - -5	31.1	27.24	34	29.02	46.63
-5 - 0	62.84	51.98	55.35	62.02	36.98

Table 3 Preproduction 47-FT Pitch (Bow Down) Frequency Distribution

Pitch (degrees)	47204 (%occurrence out of 658 hrs)	47201 (%occurrence out of 495 hrs)	47203 (% occurrence out of 531 hrs)	47205 (%occurrence out of 825 hrs)	47202 (%occurrence out of 731 hrs)
0-2	88.45	91.08	96.83	95.67	99.38
2-4	6.94	5.89	1.63	2.47	0.46
4-6	2.86	1.85	0.78	0.97	0.11
6-8	1.14	0.67	0.38	0.57	0.02
8-10	0.3	0.24	0.13	0.22	0
10-12	0.1	0.07	0.16	0.06	0
12-14	0.08	0.07	0.03	0.04	0
14-16	0.1	0.1	0	0	0
16-18	0	0.03	0.06	0	0
18-20	0	0	0	0	0.02
20-22	0.03	0	0	0	0

Heave Acceleration Frequency Distributions:

The heave acceleration frequency distributions were developed using the identical sorting approach applied to the roll and pitch motion statistics. The heave data are referenced to 1g (32 ft/sec^2) or simply stated, the boat experiences 1g at rest with no heave motions. Heave values collected with RPM readings less than 200 RPM were not included in this analysis. Using heave data associated with 200 RPM readings and higher insure that the heave distribution curves are representative of underway engine use. Table 4 presents the results of this analysis. Figures 15 through 19 present the heave acceleration distribution curves of each MLB. The bar charts in Figures 15 through 19 can be used by selecting the heave acceleration range of interest. For example, Station Tillamook's 47203, Figure 17, will experience a range of 1.6-1.7 g's of peak heave acceleration 7% of the time the boat gets underway.

Table 4 Preproduction 47-FT MLB Heave Acceleration Frequency Distribution

Heave (g's)	47201 (%occurrence out of 495 hrs)	47203 (%occurrence out of 531 hrs)	47205 (%occurrence out of 825 hrs)	47204 (%occurrence out of 658 hrs)	47202 (%occurrence out of 731 hrs)
0.5-0.6	0	0	0	0	0
0.6-0.7	0	0	0	0	0
0.7-0.8	0	0	0	0.13	0
0.8-0.9	0	0.13	0.18	1.01	0.09
0.9-1.0	1.15	0.63	1.48	3.22	4.81
1.0-1.1	16.94	3.64	31.04	42.05	28.68
1.1-1.2	38.57	56.45	32.51	12.16	24.21
1.2-1.3	6.6	0	9.79	6.99	8.83
1.3-1.4	9.7	22.79	10.31	6.31	15.45
1.4-1.5	10.64	0	6.93	16.29	10.27
1.5-1.6	10.98	8.16	5.22	7.17	5.8
1.6-1.7	2.83	7.03	1.46	3.19	1.1
1.7-1.8	1.31	0	0.57	0.96	0.41
1.8-1.9	0.4	1.07	0.28	0.38	0.16
1.9-2.0	0.27	0	0.18	0.1	0.11
2.0-2.1	0.34	0.03	0.06	0.03	0.09
2.1-2.2	0.07	0	0	0	0
2.2-2.3	0.1	0.06	0	0	0
2.3-2.4	0.1	0	0	0.03	0

3.2 Engine RPM Statistics Analysis

A concern under the Maintainability Critical Operational Issue (COI) identified in Reference [2] involved the Mean Time Between Overhaul (MTBO) of the preproduction boat engines. The premature failures of the Detroit Diesel engines on the preproduction MLBs prompted the development of long-term engine usage profiles from the MDR data. The MDRs collected average RPM information on the port engines every 10 minutes the boats were underway. These data have been sorted into RPM bins to generalize the boat's usage. The RPM data was sorted into 150 RPM bins in a range from 200 to 2300 RPM.

The individual MLB results are presented in Table 5 and plotted as bar charts in Figures 21 through 25. Although these data do not give a complete picture of engine usage, e.g., throttling transients, splitting of throttles, etc., they do provide a good general profile of the engines usage. It is apparent from the individual engine usage profiles that the 47201 and 47202 spent significantly more underway time at the higher RPM range, around 2000 RPM, than all of the other boats. It may be more than a coincidence that in 1994 both the 47201 and 47202 experienced engine failures at less than 1200 hours of operation.

A composite engine usage profile was developed which includes all the data from the preproduction MLBs. This is presented in Table 6 and is plotted as a bar graph in Figure 20. The composite profile represents 3,240 hours of underway time for all the MLBs. The composite engine usage profile, Figure 20, can be used by selecting a specific RPM operating range of interest. For example, it can seen that the MLBs spend, as a whole, 30% of their time operating in a range of 650 to 800 RPM (approximately 7 knots) and less than 7% of the time above 2000 RPM (approximately 23-24 knots). Someone not familiar with small boat station Search & Rescue (SAR) operations might conclude that the Coast Guard does not need an MLB that can go 24 knots (>2150 RPM) since most of its underway time is spent at speeds of 5-10 knots. However, the reality is that the MLBs will get underway(to a case) and reach a distressed vessel at full throttle in a short time but may require 4-5 times more time per case at low RPMs towing a vessel back to safety. Examples of this scenario were shown in Reference [4] when specific towing missions were cross-correlated to MDR statistics for that time frame. The MLBs also spend a significant portion of their time cruising at lower RPMs when they are getting underway and returning in proximity to their stations. The composite RPM profile demonstrates that the MLBs didn't spend much time in the 1250 and 1400 RPM bins. This is in an inefficient speed range where the MLBs are transitioning to planing speed.

Table 5 Preproduction 47-FT MLB RPM Usage Profiles

MDR recorded RPM	47201 (% Usage out of 495 hrs)	47203 (% Usage out of 531 hrs)	47205 (% Usage out of 825 hrs)	47204 (% Usage out of 658 hrs)	47202 (% Usage out of 731 hrs)
200-350	2.59	1.35	1.25	2.74	0.75
350-500	1.92	1	1.31	1.42	0.82
500-650	2.39	1.26	0.73	1.04	2.58
650-800	20.71	21.37	37.4	33.46	30.25
800-950	17.71	22.44	11.81	8.92	7.99
950-1100	8.15	9.1	7.18	6.79	6.16
1100-1250	7.85	6.43	10.33	7.47	6.53
1250-1400	4.68	4.14	4.08	4.18	4.77
1400-1550	3.94	7.16	3.44	3.42	4.86
1550-1700	2.29	3.61	8.19	10.36	3.63
1700-1850	2.42	5.37	9.56	15.32	6.18
1850-2000	20.51	9.92	4.53	1.34	6.25
2000-2150	4.85	6.84	0.2	3.42	17.25
2150-2300	0	0	0	0.13	1.98

Table 6 Preproduction 47-FT MLB RPM Composite Usage Profile of 47-FT MLBs

MDR Recorded RPM	Composite RPM (% Usage out of 3,240 hrs)
200-350	1.66
350-500	1.27
500-650	1.55
650-800	29.81
800-950	13
950-1100	7.33
1100-1250	7.87
1250-1400	4.36
1400-1550	4.44
1550-1700	5.95
1700-1850	8.19
1850-2000	7.59
2000-2150	6.5
2150-2300	0.47

3.3 Area of Recorded Operations (AROs)

The Areas of Recorded Operations (AROs) is defined as the latitude and longitude locations recorded by the MDR for the purposes of this project. This is not to be confused with the Areas of Responsibility (AORs). The MDR recorded a position fix every 10 minutes when the MLBs were underway. The MDR data were converted for importation to GDOC. Individual GDOC plots are displayed in Figures 26 through 30. The ARO plots represent the tracks of the 47-FT MLBs over hundreds of hours and gives a quantitative view of the range of the operations of the MLBs and where their coverage has overlapped those of other small boat stations. For example, the AROs for the 47204 demonstrate its range along the West Coast from Station Noyo to Station Cape Disappointment. Increasing the view on the individual MLB operating areas using GDOC reveals some definite tracks that the MLBs tend to patrol.

3.4 BOATVU Animation Enhancements

In Phase 3 some additional work was done on the MDR animation software. The animation program called BOATVU was originally developed for the DOS operating environment. In Phase 3 it was converted to a Microsoft Windows 3.1 operating environment so that the software could also run on the Coast Guard's new Standard Workstation III which employs Microsoft Windows NT. A 3D solid model rendition of the 47-FT MLB was developed to eliminate past confusion when looking at the wire frame model. It was often difficult to ascertain what the actual orientation of the boat was when looking through a wire frame model. One half of the 3D boat model was colored red and the other half green. A pre-processing program was also developed to directly read the MDR data and automate the creation of event and statistics files.

4 Summary/Conclusions

This report presents a final compilation of MDR statistics data that have been collected for the past two years. The MDRs have been removed from the 47-FT preproduction MLBs. A total of 10 significant roll events, hundreds of hours of tracking the locations of the MLBs, and hundreds of underway hours of motion statistics and engine usage have been captured and analyzed in the three phases of data collection. This represents the most comprehensive database of underway information every collected on a Coast Guard MLB. These data were used to construct engine usage profiles, and roll, pitch, and heave acceleration frequency distribution curves.

The MDRs could be put to good use as training tools at the National Motor Lifeboat School at Cape Disappointment. Future 47-FT MLB coxswains could conduct their surf drills and come back to the class room and review their training experience with the BOATVU program. The school could retain the most interesting events in a video/computer library that could be shared with coxswains. With some additional work, the MDR could also be configured to accept additional sensors to collect wave information encountered and provide a more comprehensive picture of the recorded event.

5 References

1. Operational Test and Evaluation Plan for the 47-FT Motor Lifeboat.

2. Operational Test and Evaluation (OT&E) Report 47-FT Motor Lifeboat of the Motor Lifeboat Acquisition Program, December 1994.

3. Coast Guard Mission Data Recorder (MDR) for the 47-FT Motor Lifeboat, USCG R&D Center Report No. CG-D-20-94.

4. Coast Guard Mission Data Recorder (MDR) for the 47-FT Motor Lifeboat - Phase 2, USCG R&D Center Report No. CG-D-17-95.

5. 47-FT Motor Lifeboat Tactical Maneuvering Reverification Testing, USCG R&D Center Report No. CG-D-07-96.

6. Technical Evaluation of the CG-47201 6V-92 Detroit Diesel Electronic Control (DDEC) Propulsion Modification, USCG R&D Report No. CG-D-14-95.

Event Summary Plot Key:

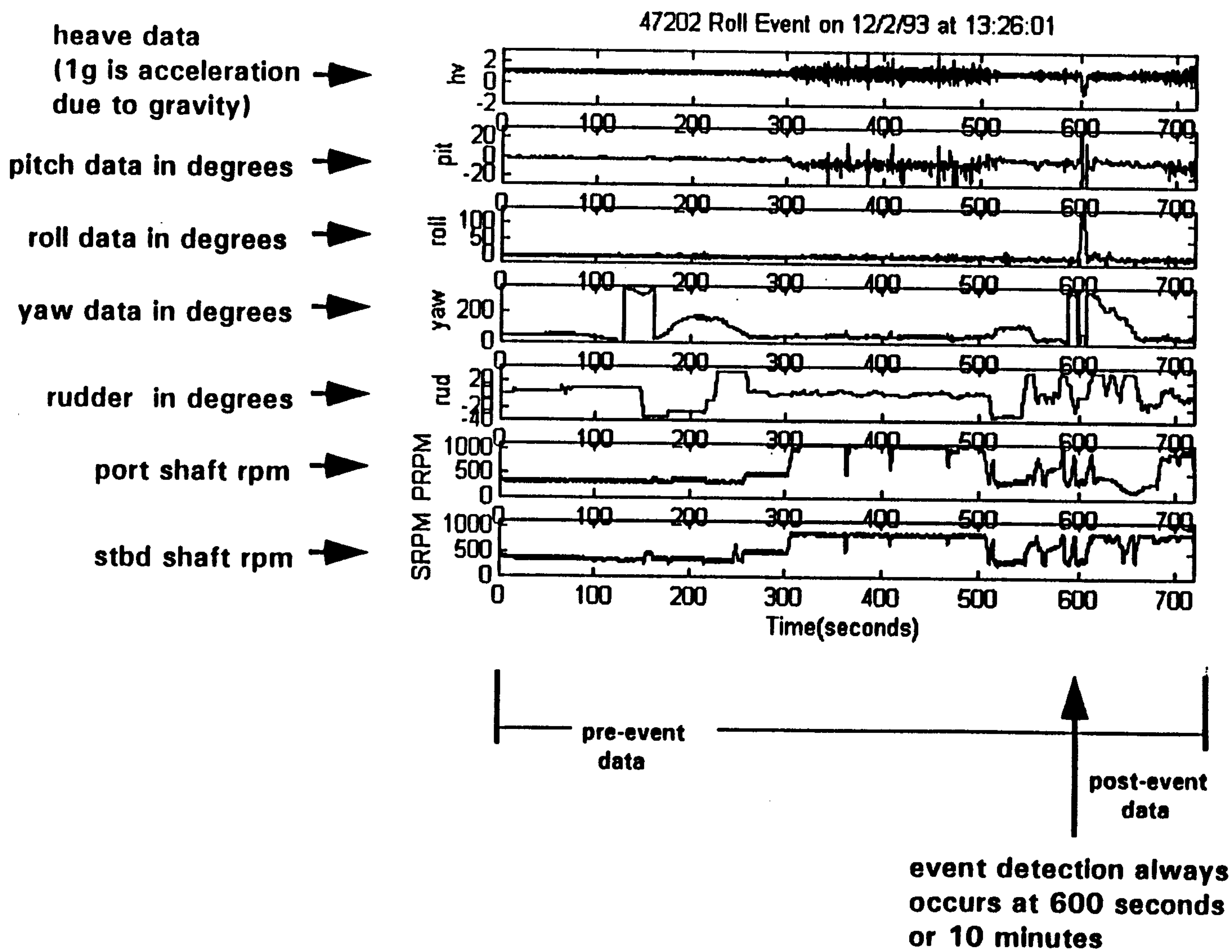


Figure 2 Event Summary Plot Key

Animation Snapshot Plot Key:

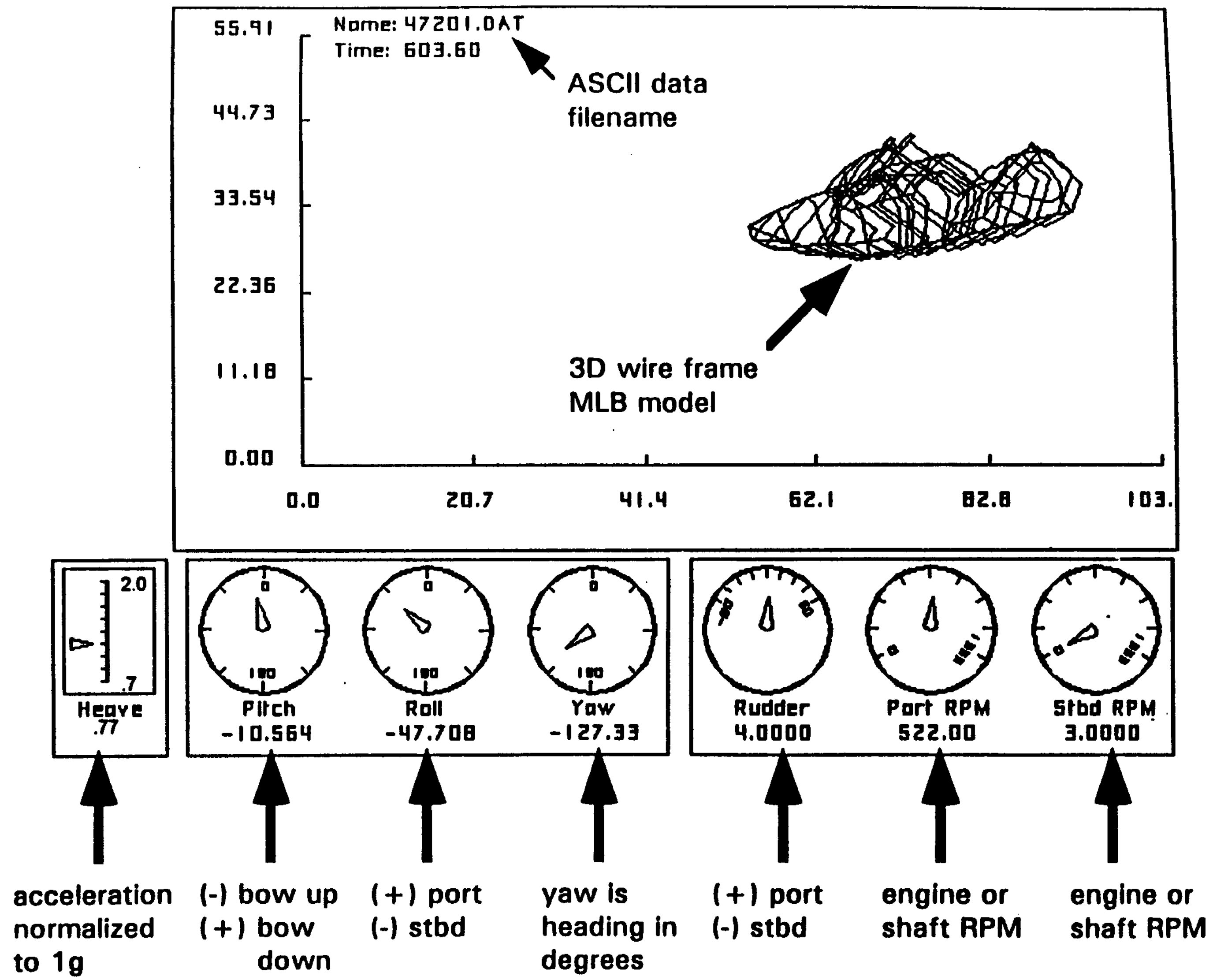


Figure 3 Key to Interpretation of Virtual Instruments

Area of Recorded Operations (AROs) using the Geographical Display Operations Computer (GDOC) Summary Plot Key:

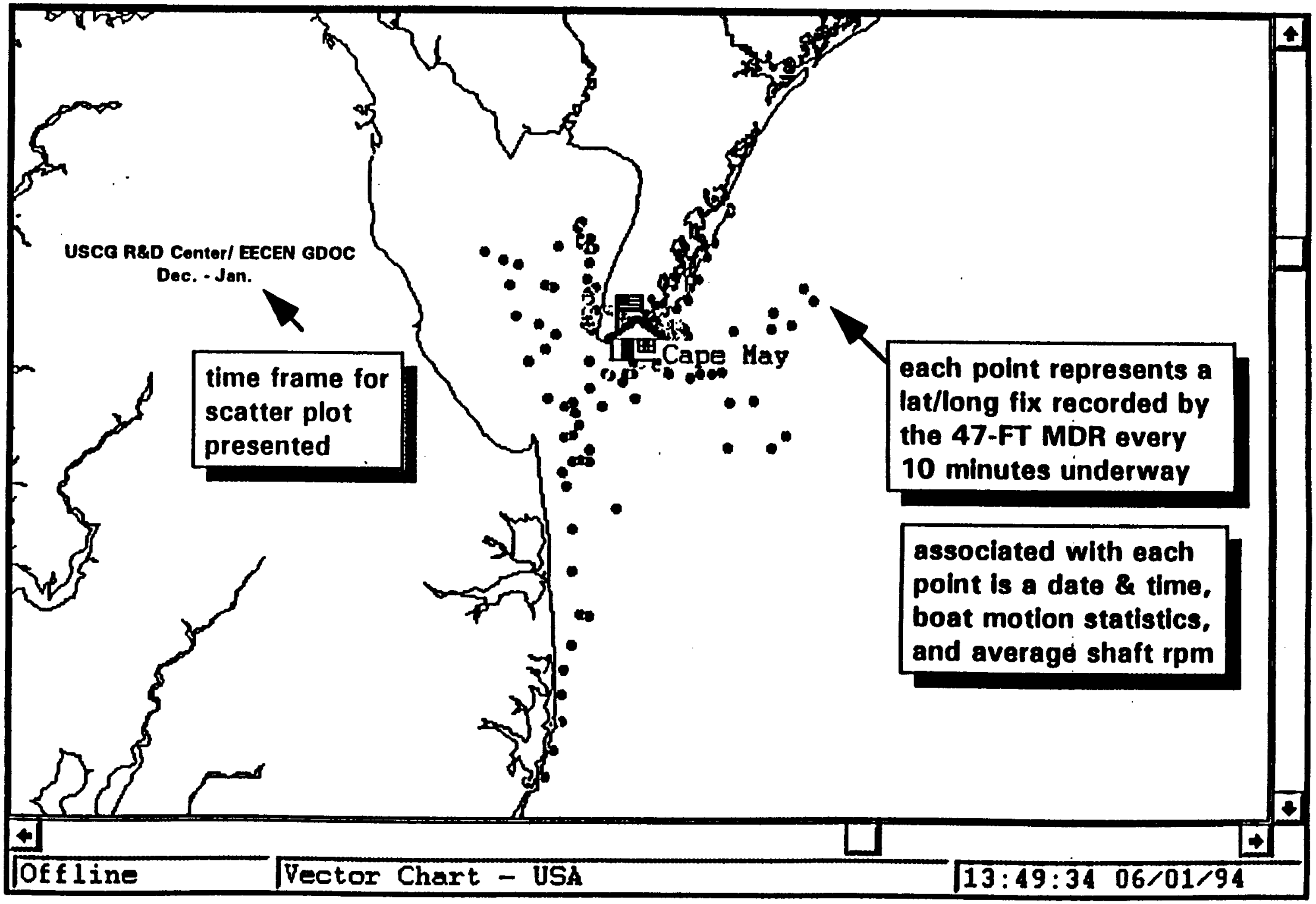


Figure 4 Area of Recorded Operation (ARO) Plot Key

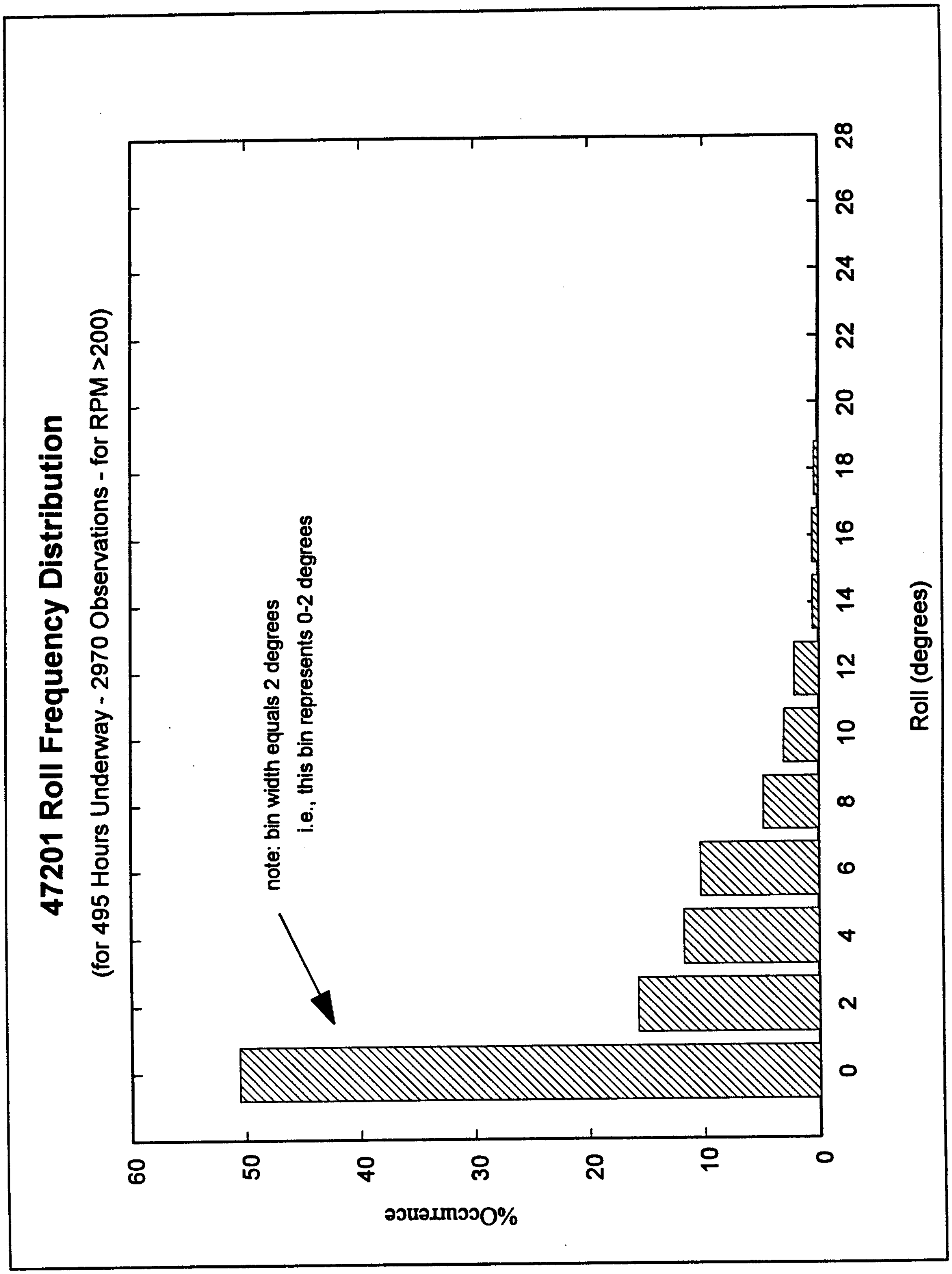


Figure 5 47201 Roll Frequency Distributions

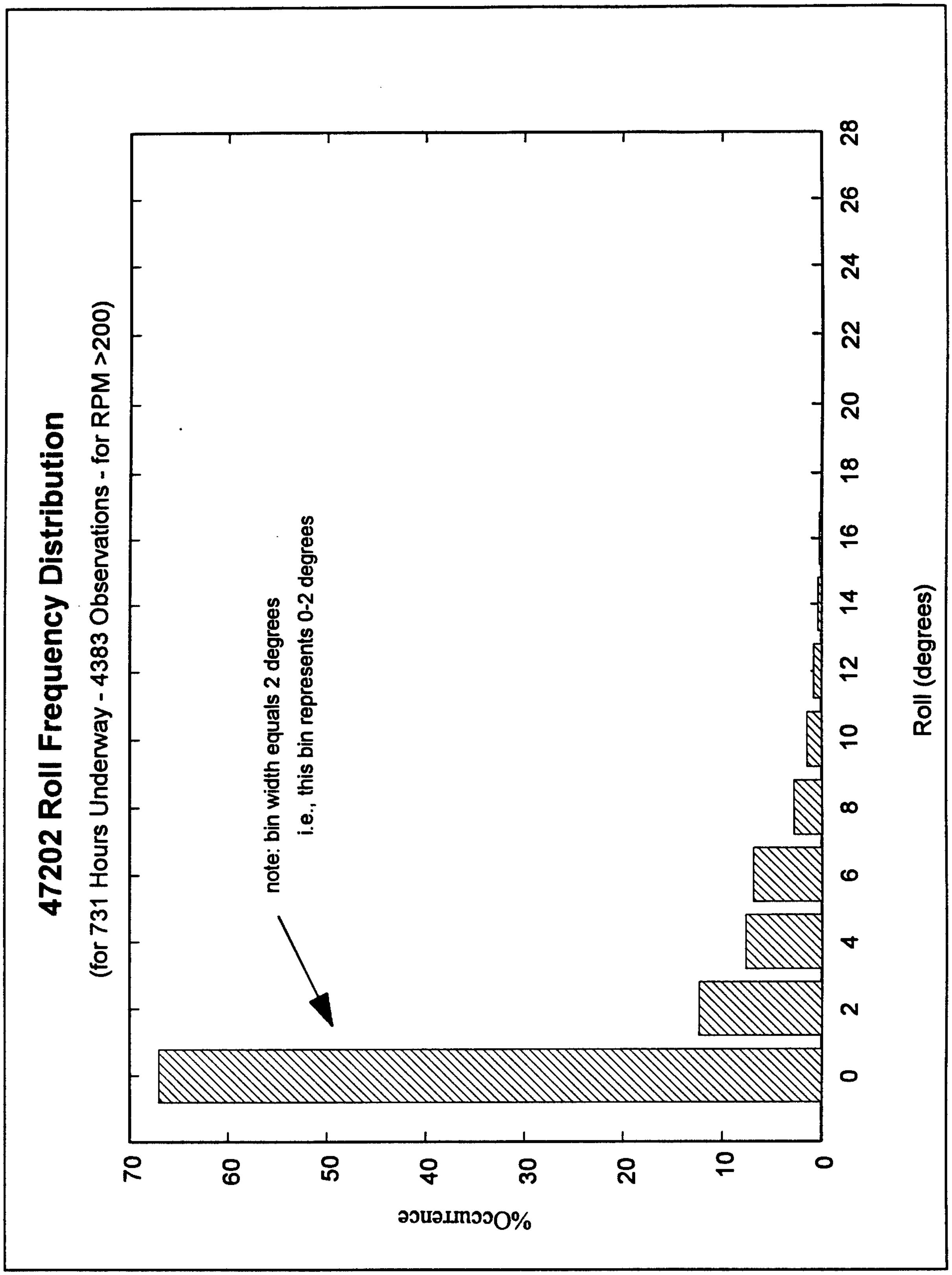


Figure 6 47202 Roll Frequency Distributions

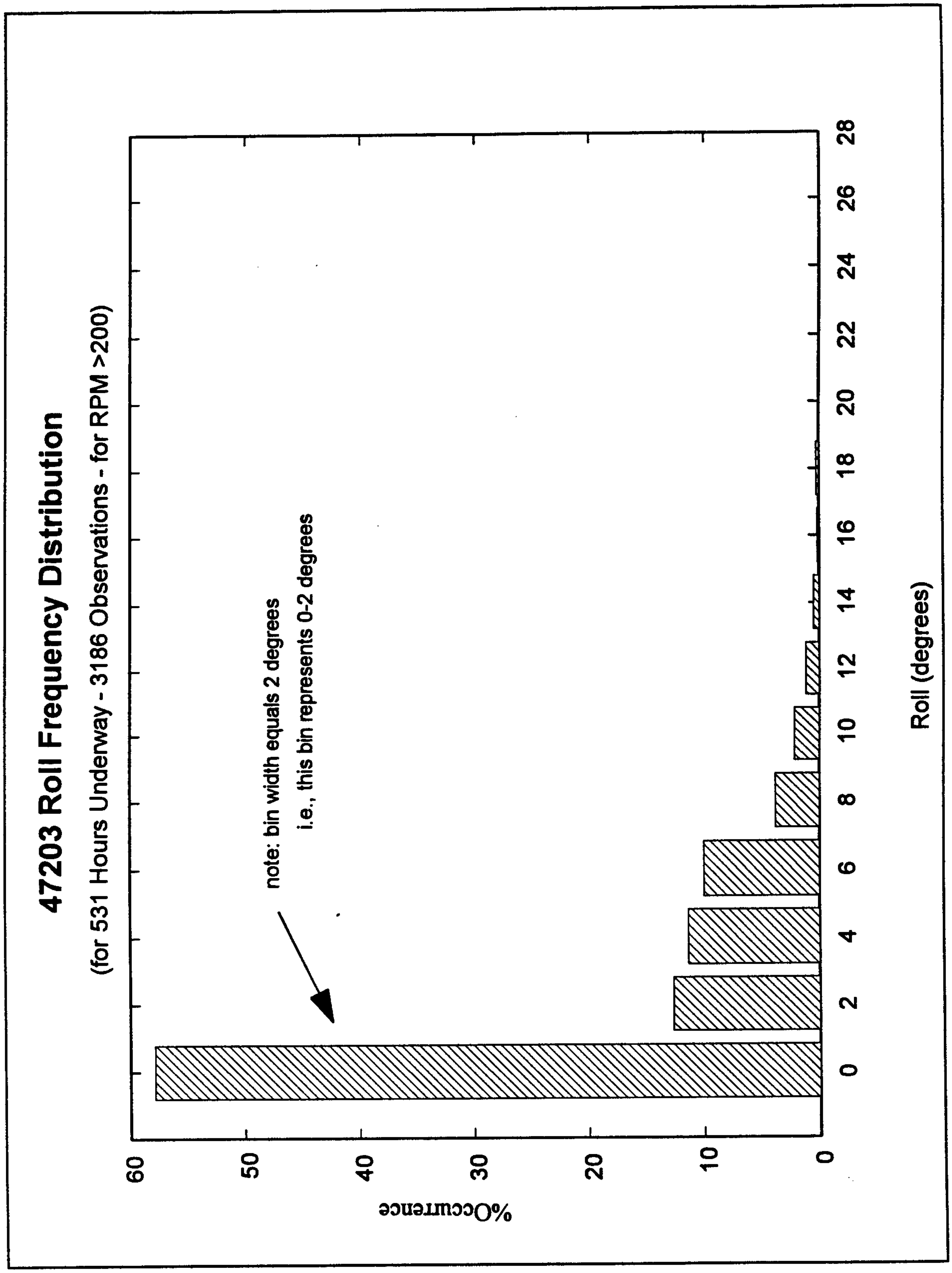


Figure 7 47203 Roll Frequency Distributions

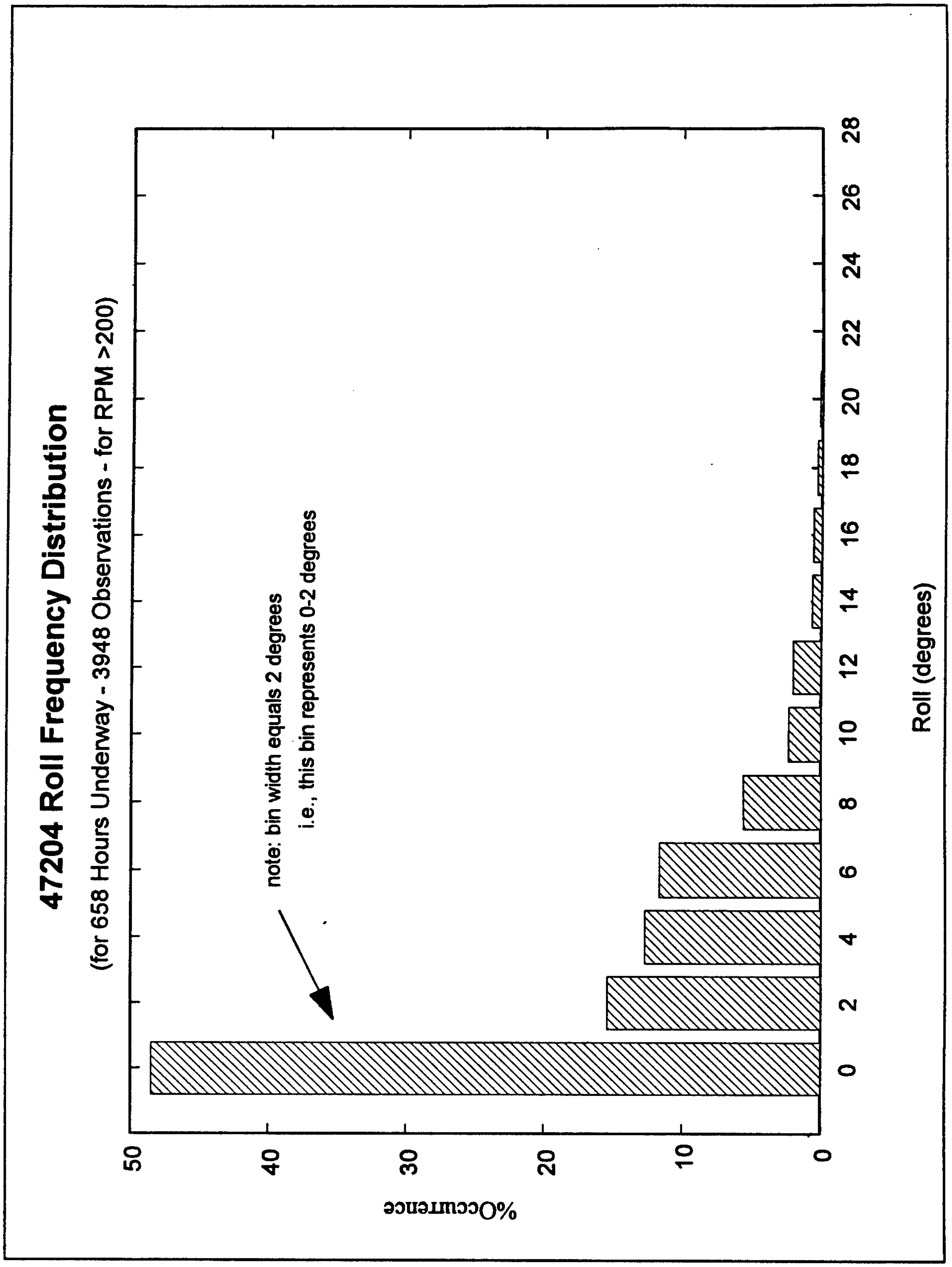


Figure 8 47204 Roll Frequency Distributions

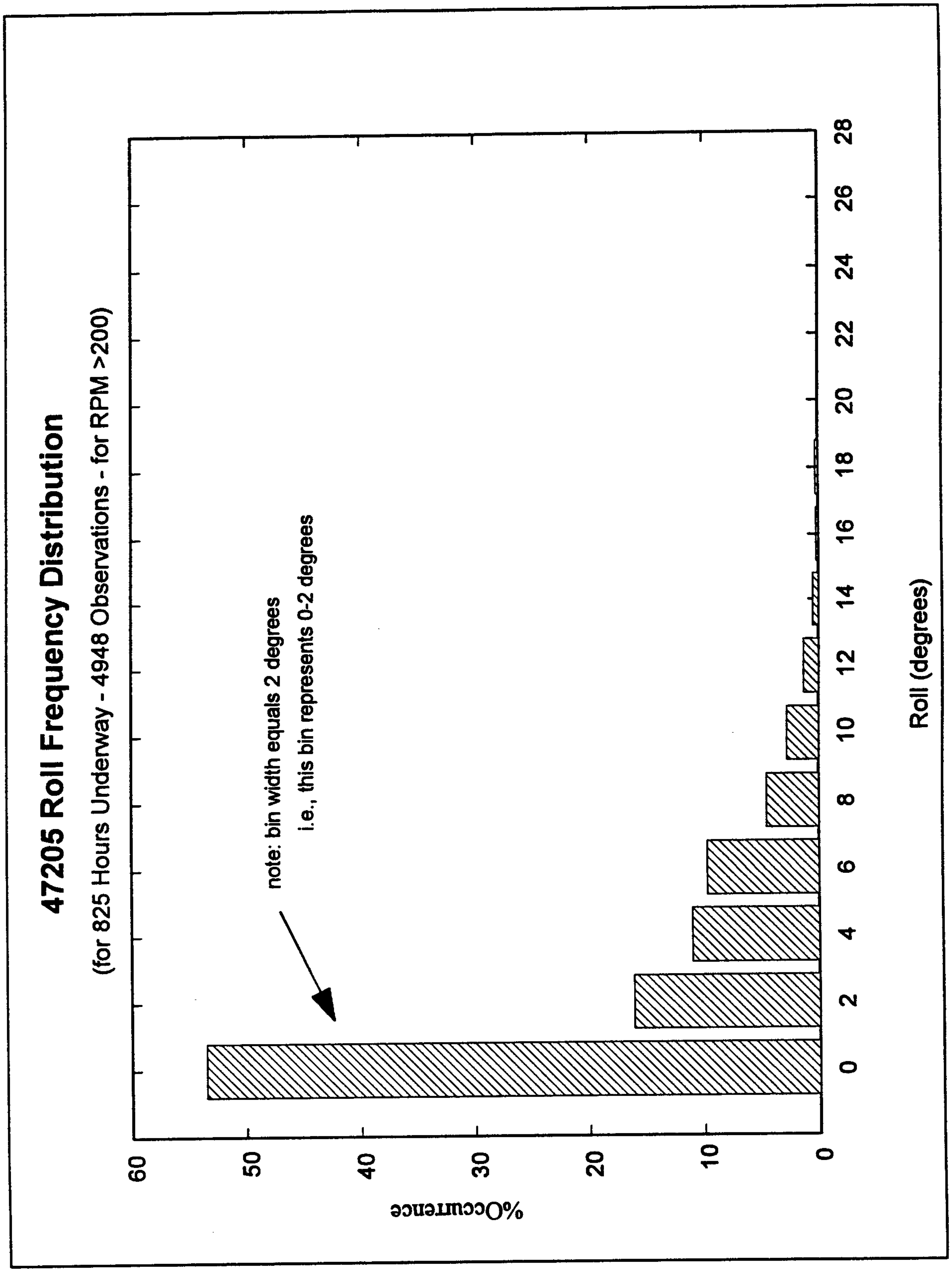


Figure 9 47205 Roll Frequency Distributions

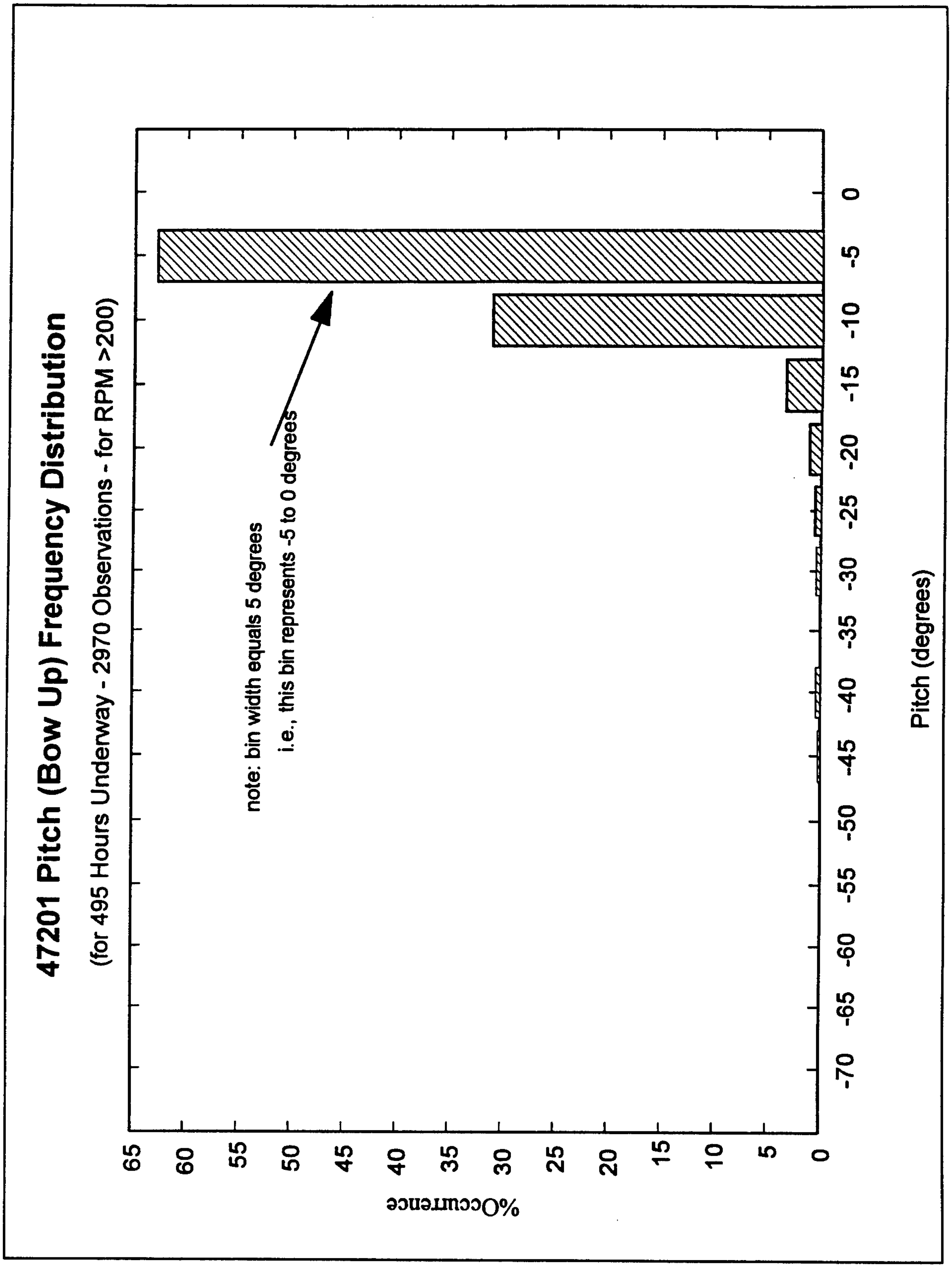


Figure 10 47201 Pitch Frequency Distribution

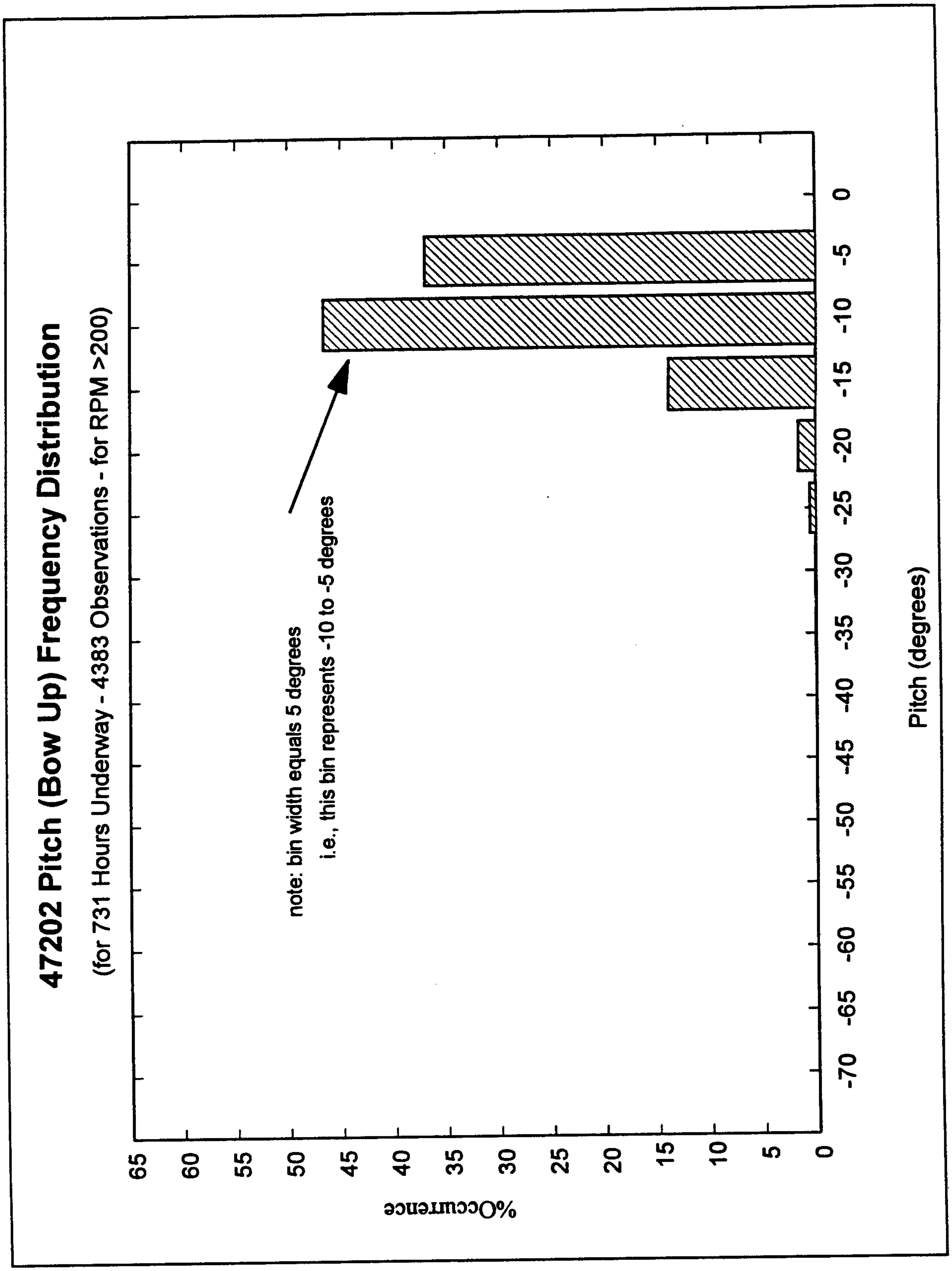


Figure 11 47202 Pitch Frequency Distribution

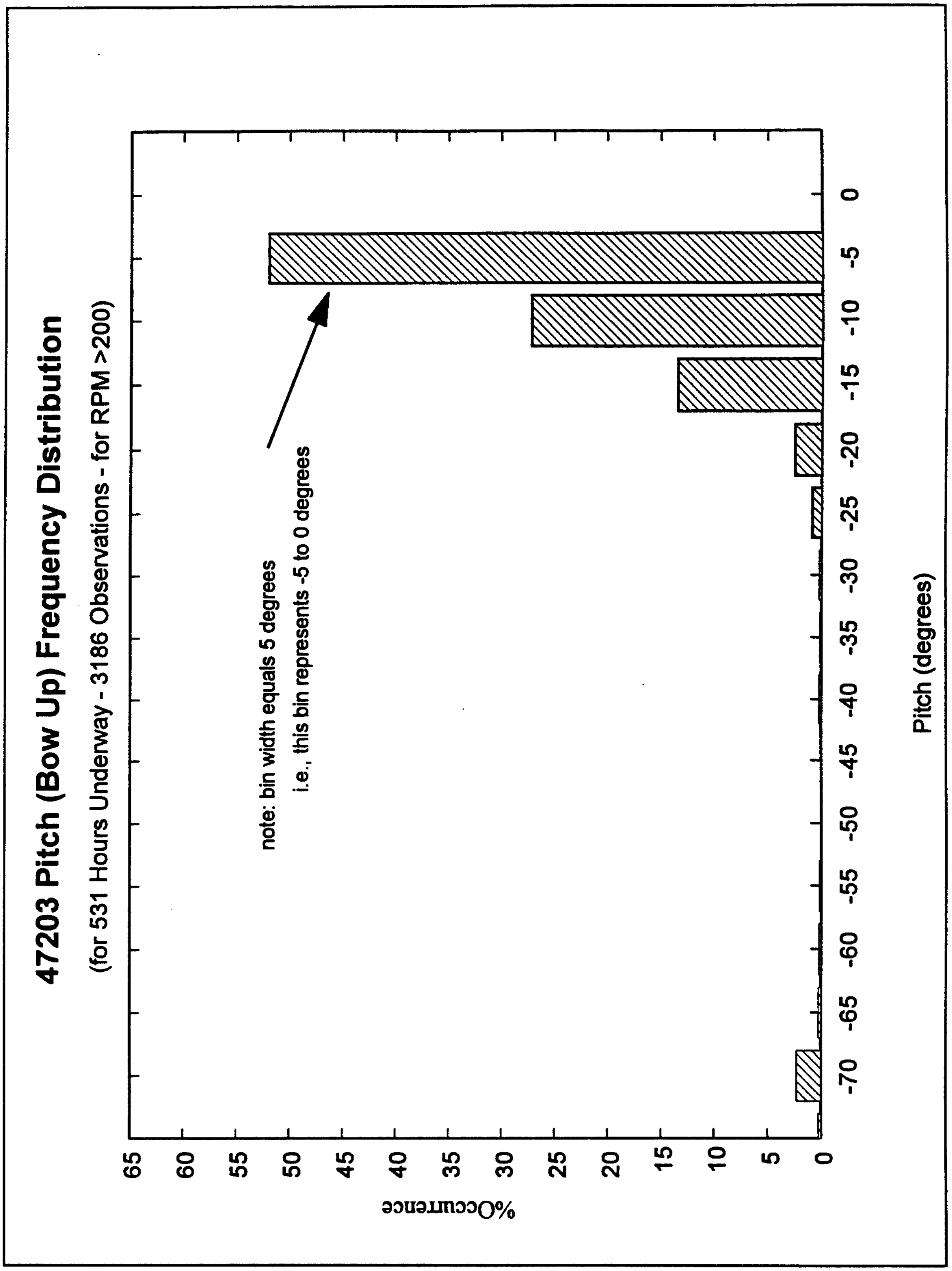


Figure 12 47203 Pitch Frequency Distribution

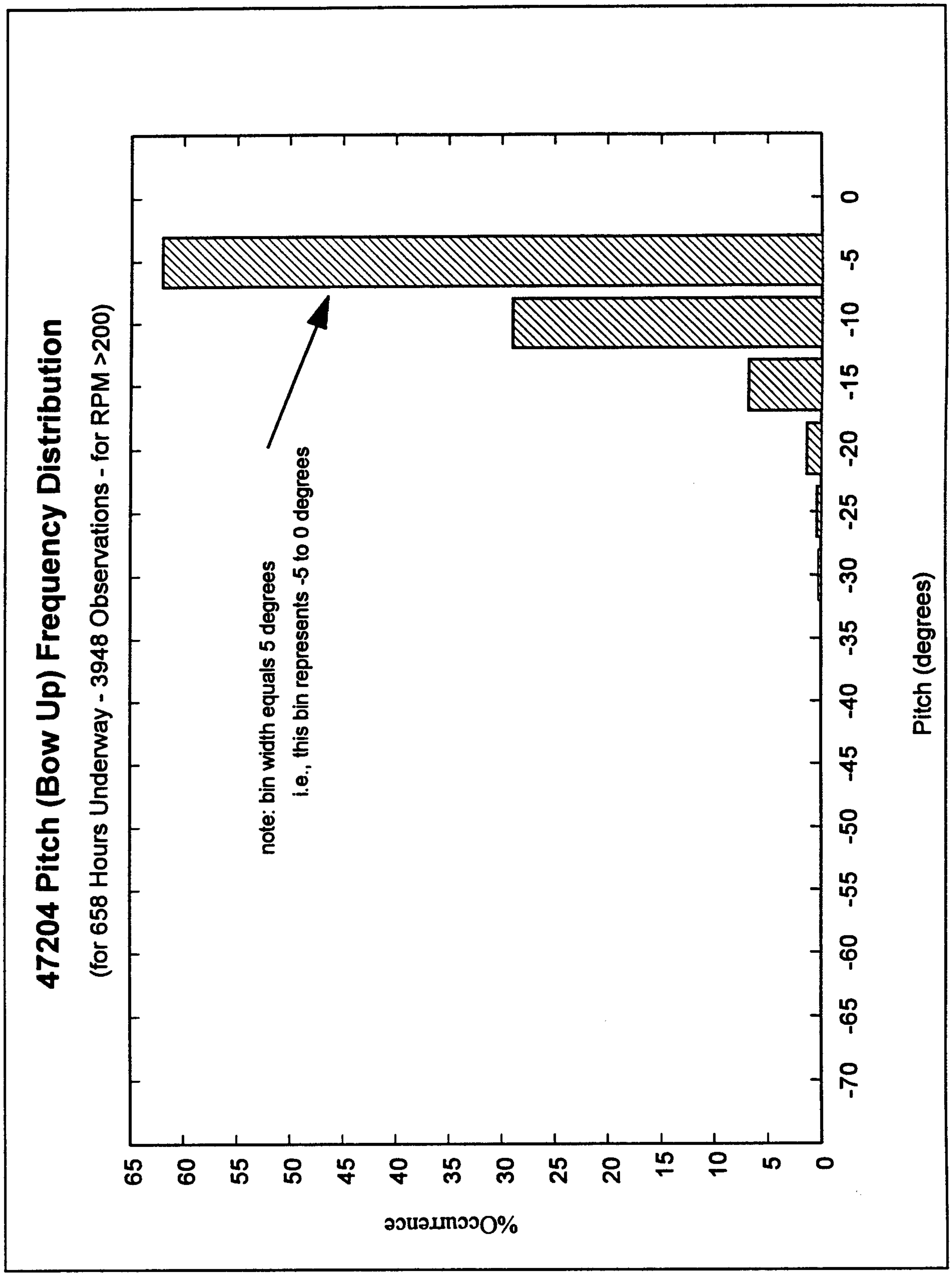


Figure 13 47204 Pitch Frequency Distribution

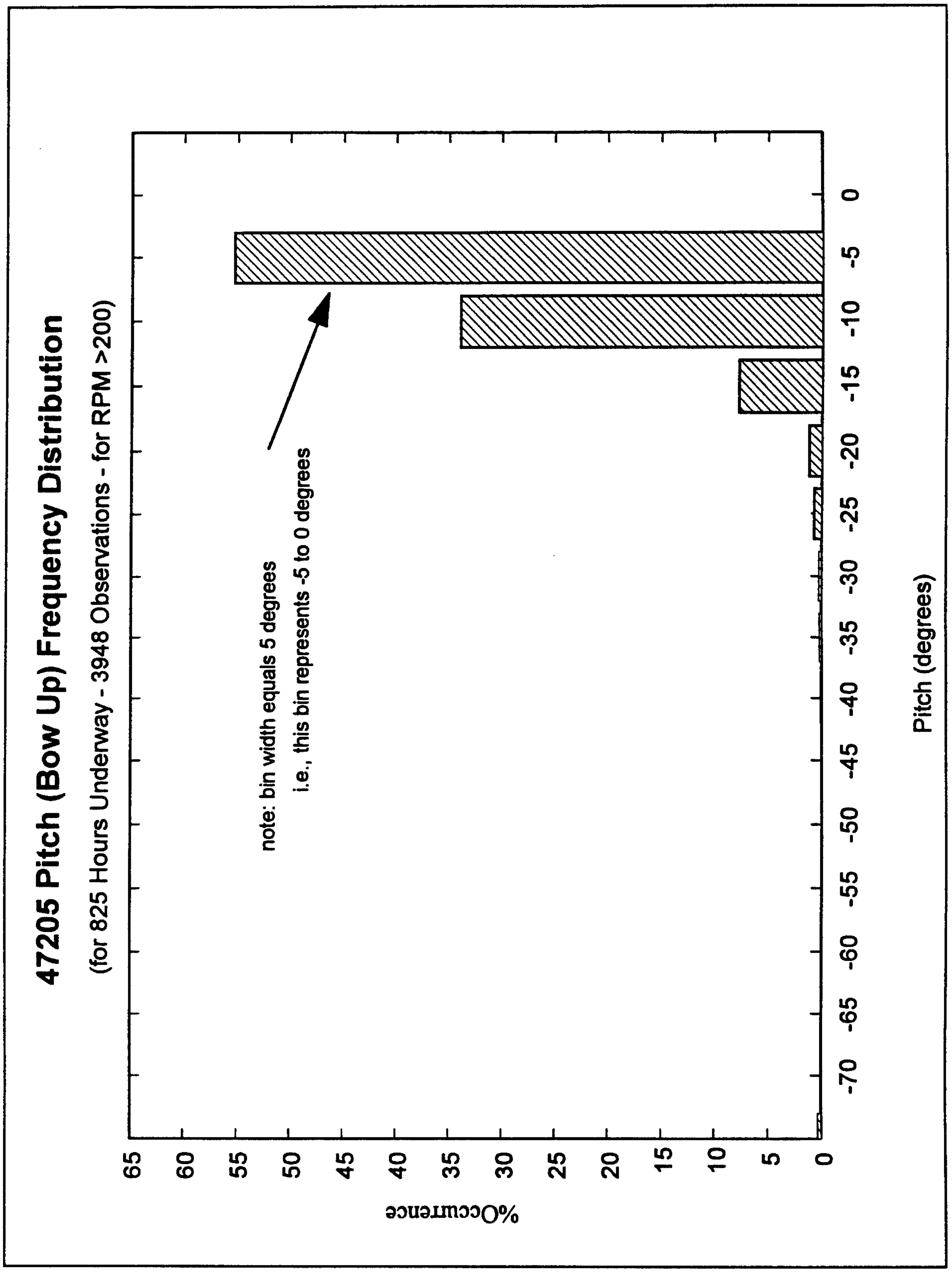


Figure 14 47205 Pitch Frequency Distribution

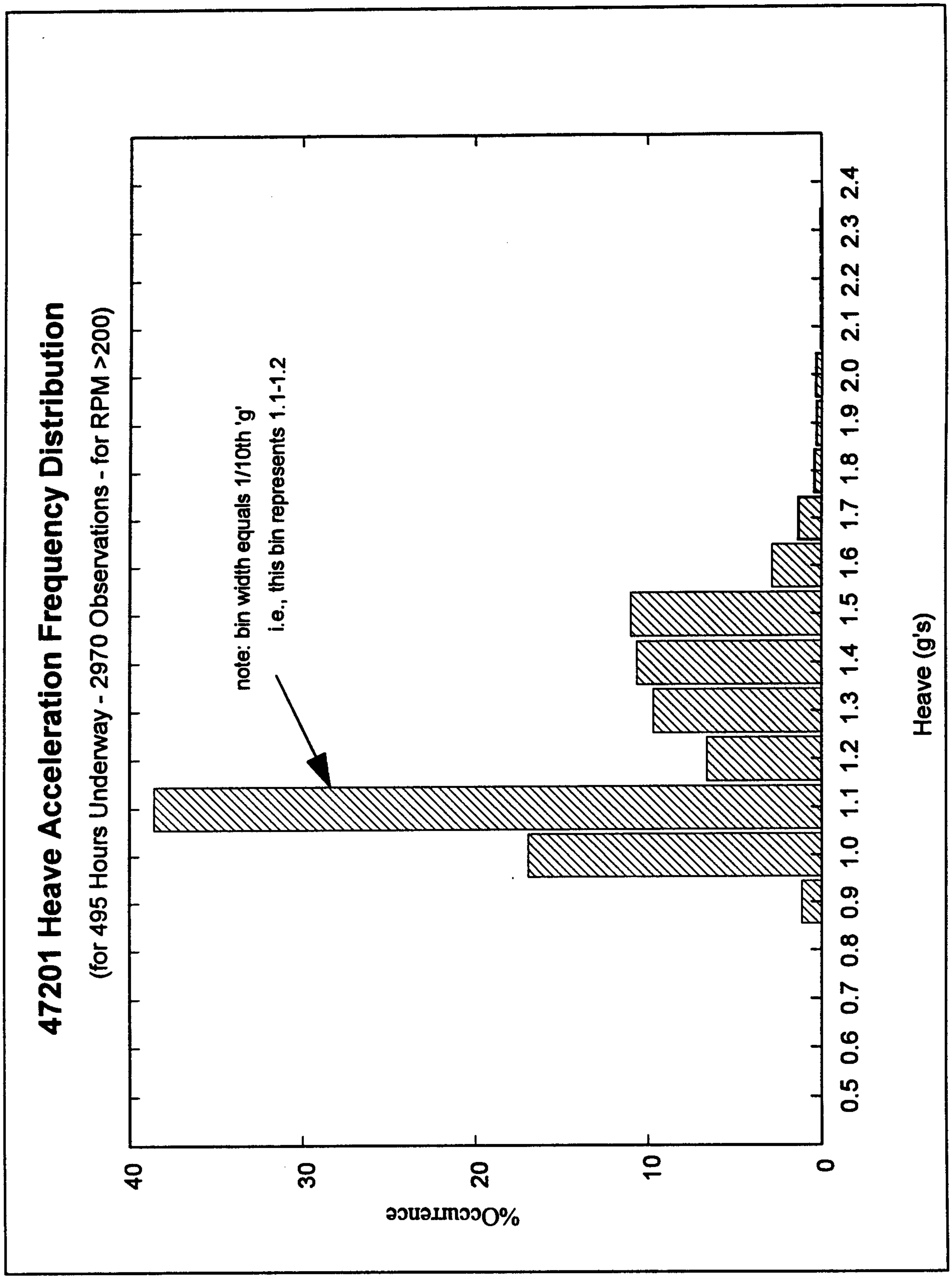


Figure 15 47201 Heave Acceleration Frequency Distribution

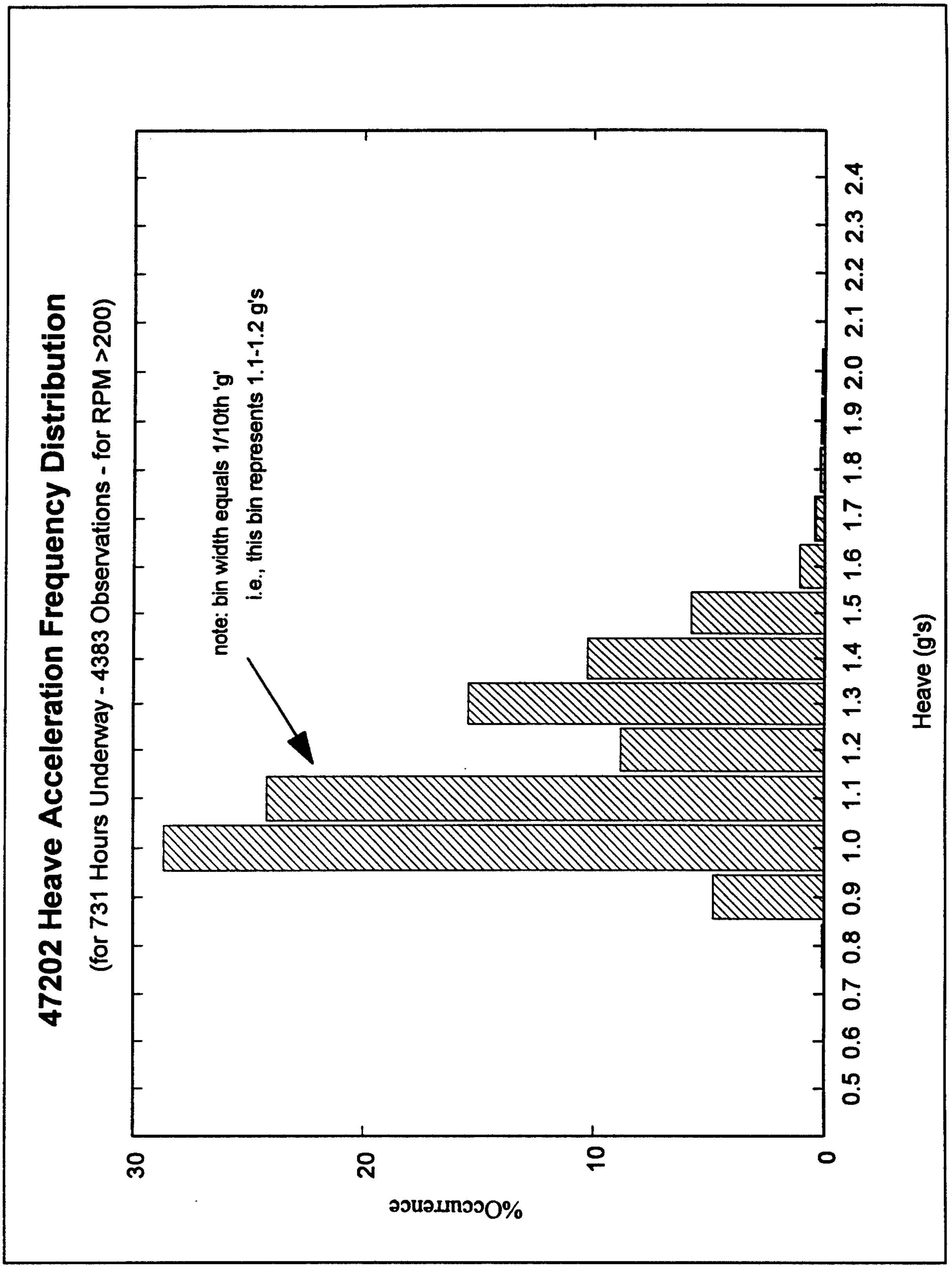


Figure 16 47202 Heave Acceleration Frequency Distribution

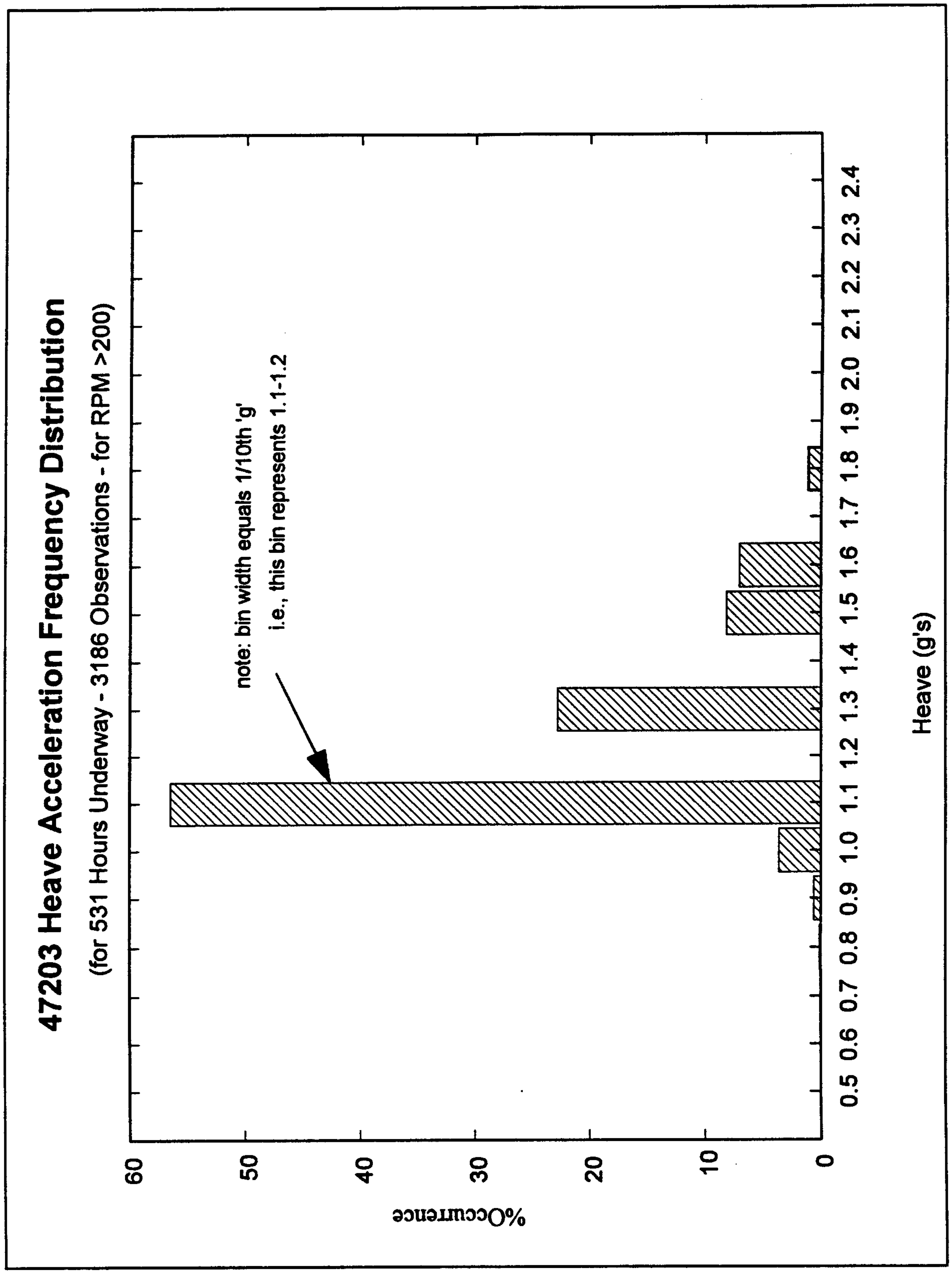


Figure 17 47203 Heave Acceleration Frequency Distribution

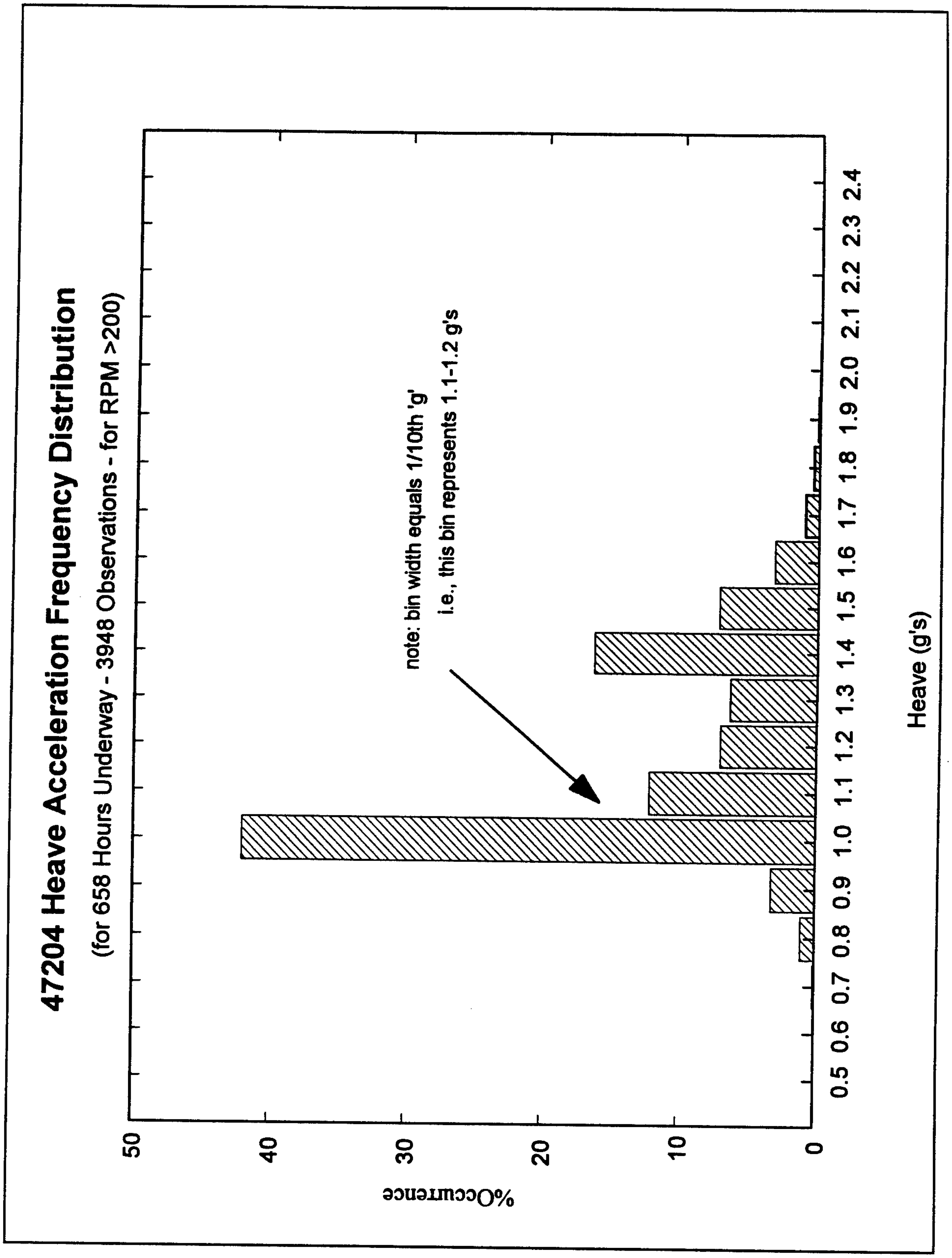


Figure 18 47204 Heave Acceleration Frequency Distribution

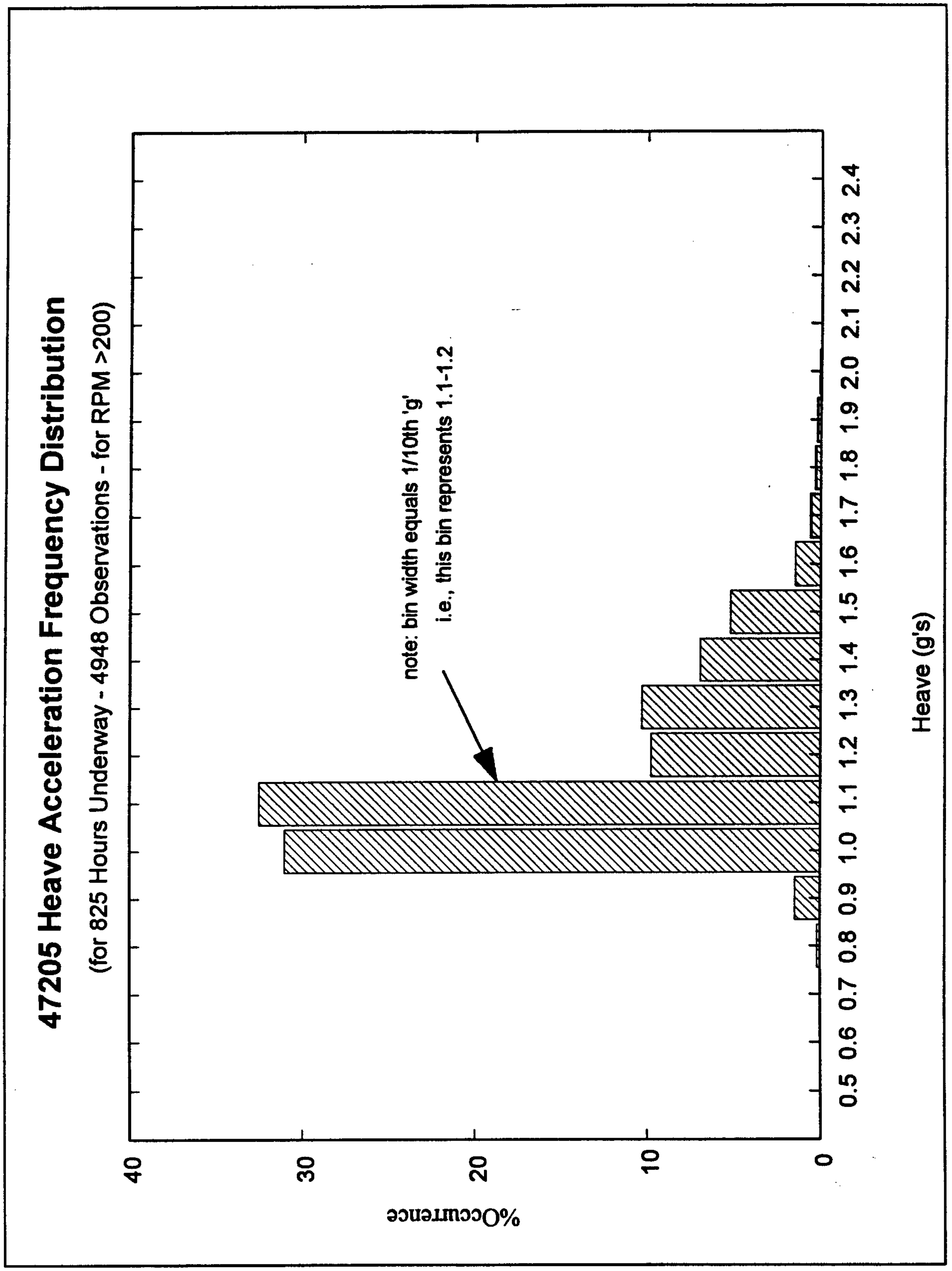


Figure 19 47205 Heave Acceleration Frequency Distribution

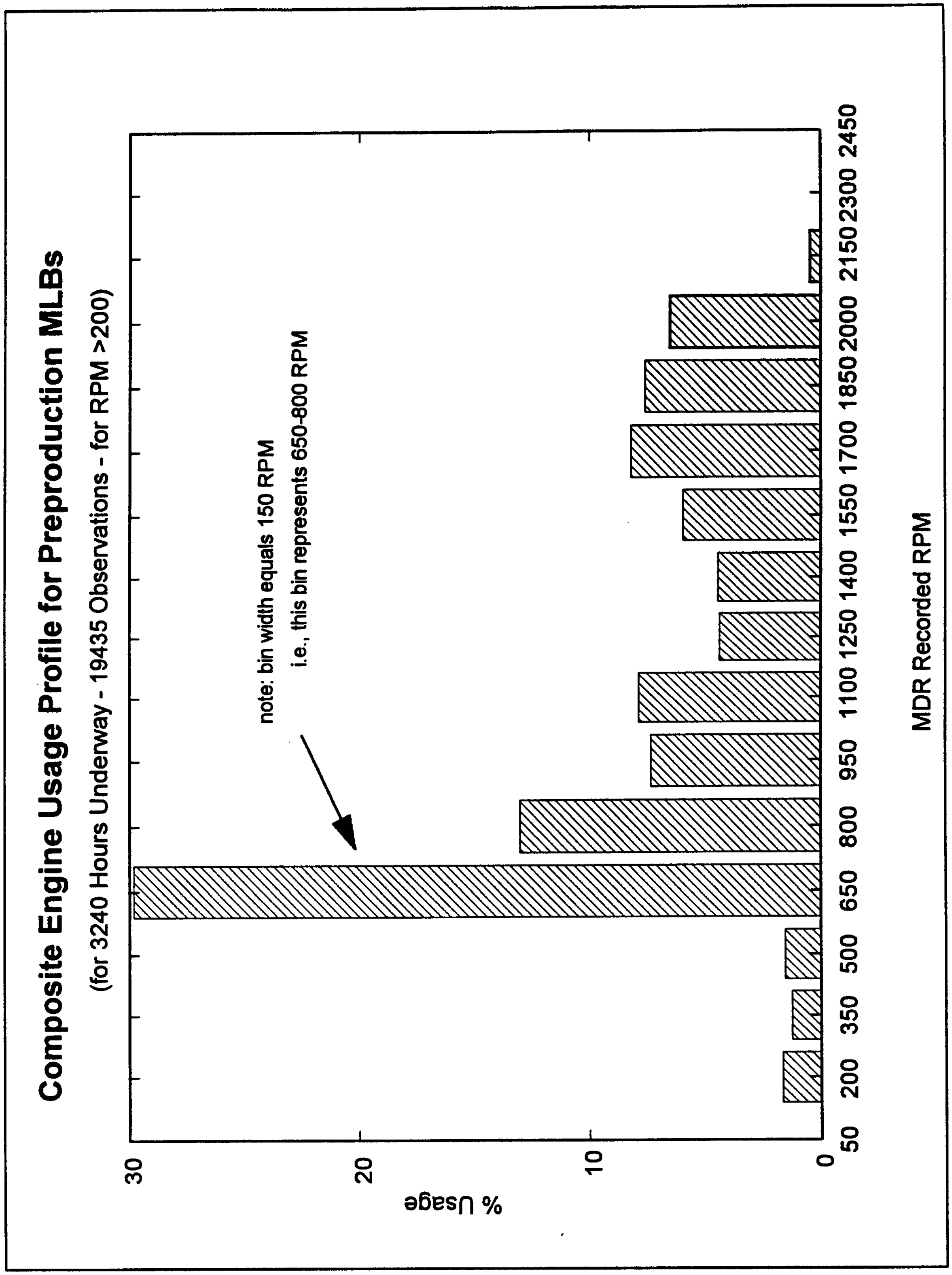


Figure 20 Preproduction 47-FT MLB Composite Engine Usage Profile

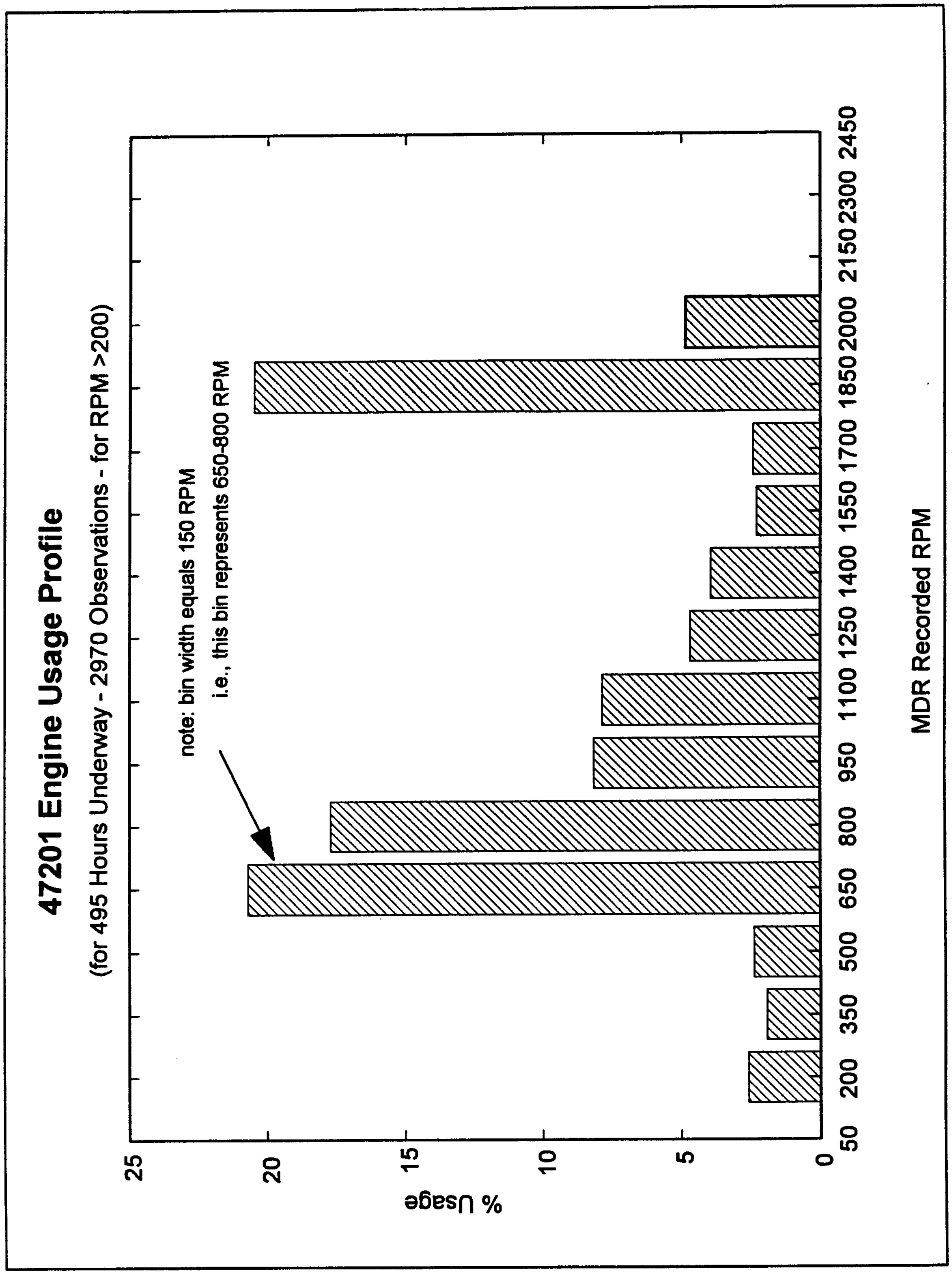


Figure 21 47201 Engine Usage Profile

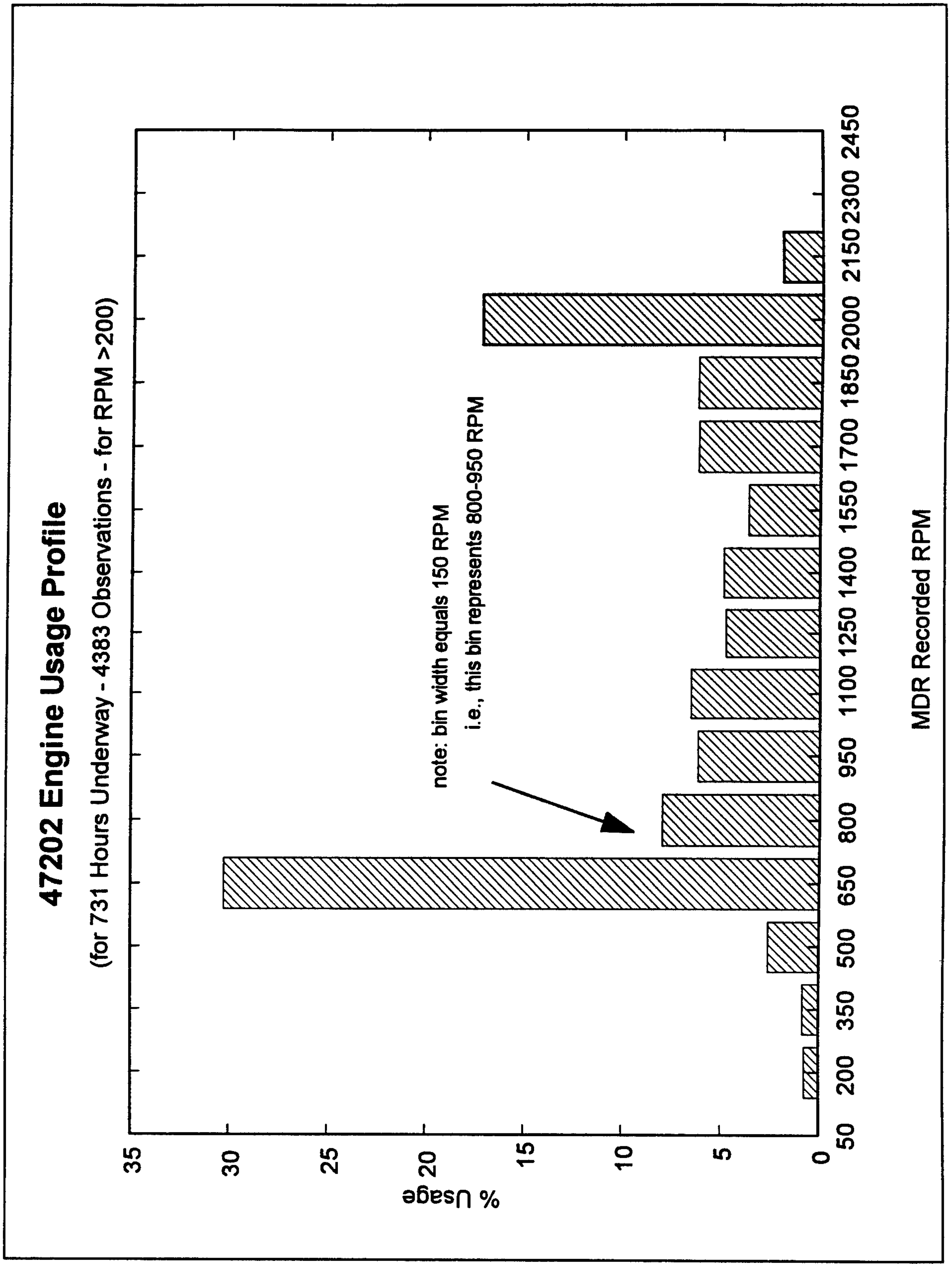


Figure 22 47202 Engine Usage Profile

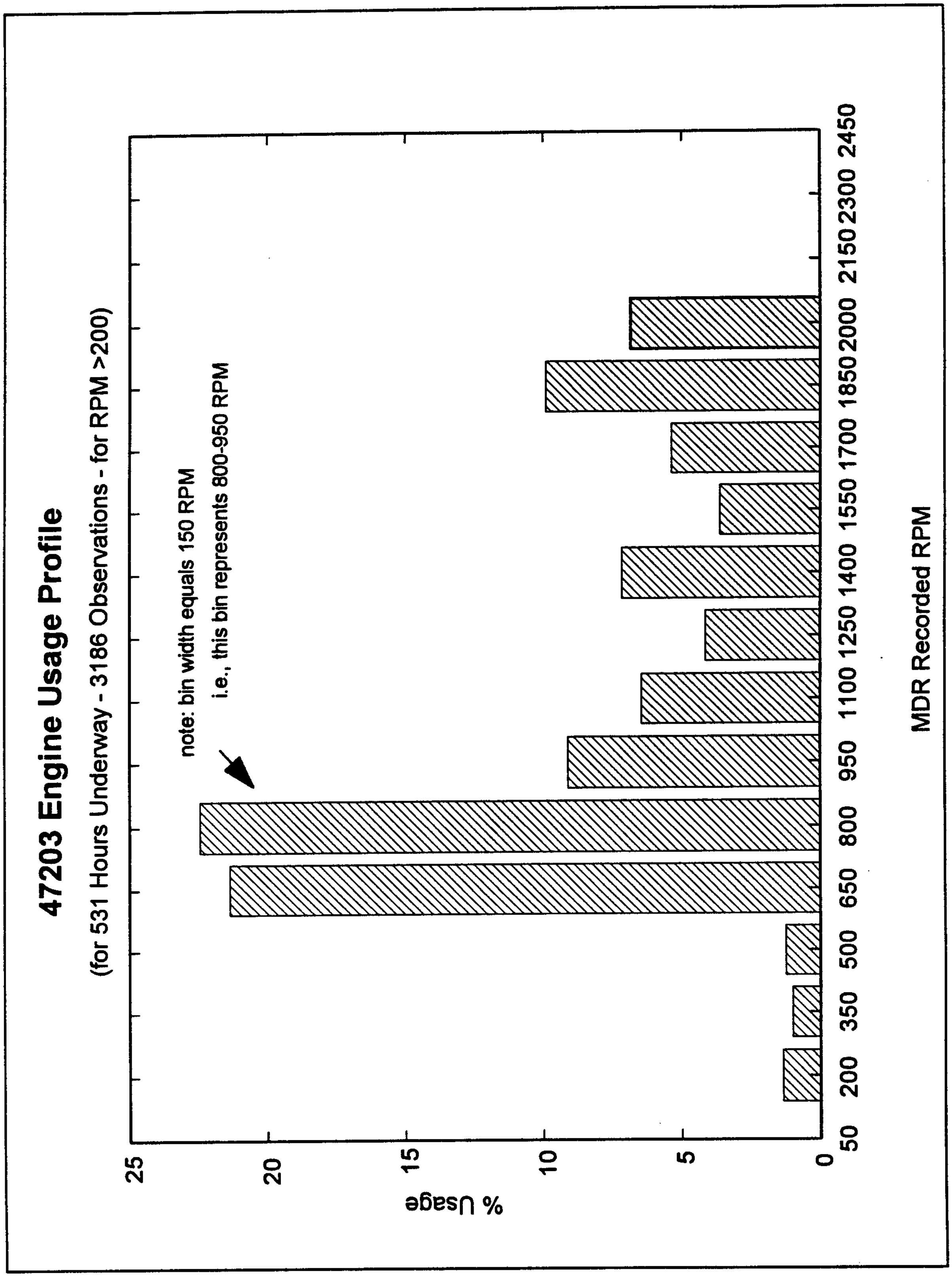


Figure 23 47203 Engine Usage Profile

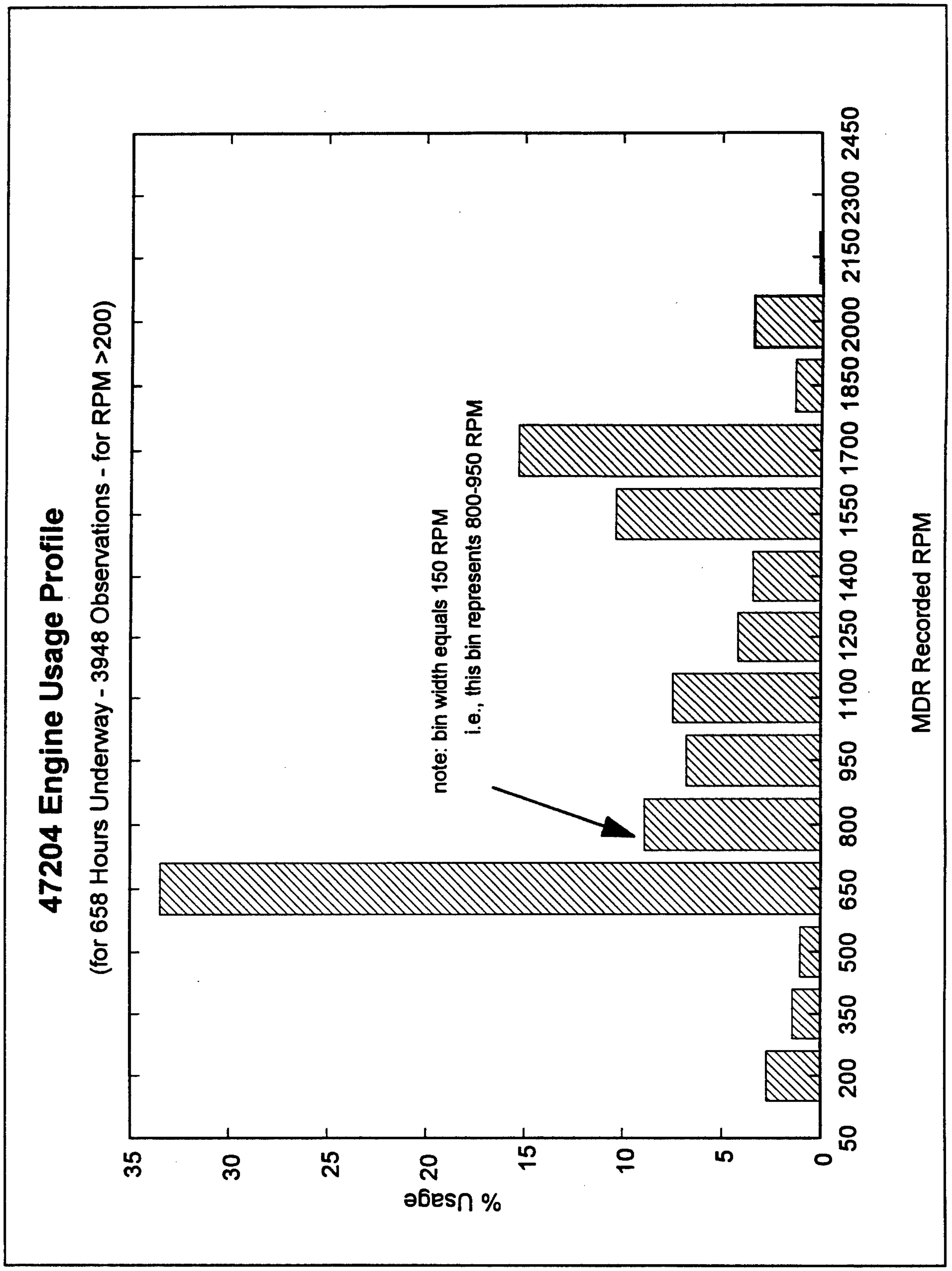


Figure 24 47204 Engine Usage Profile

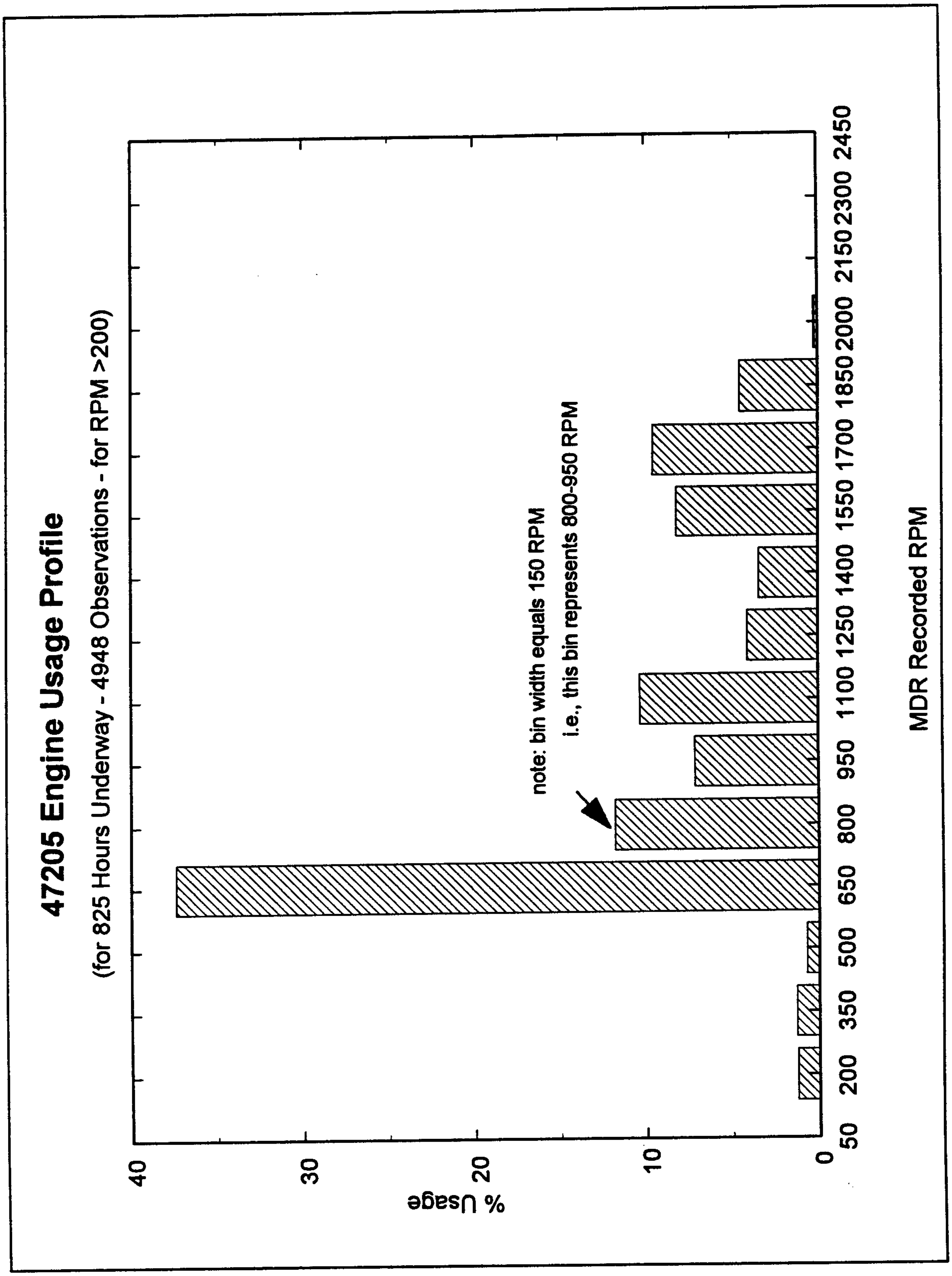
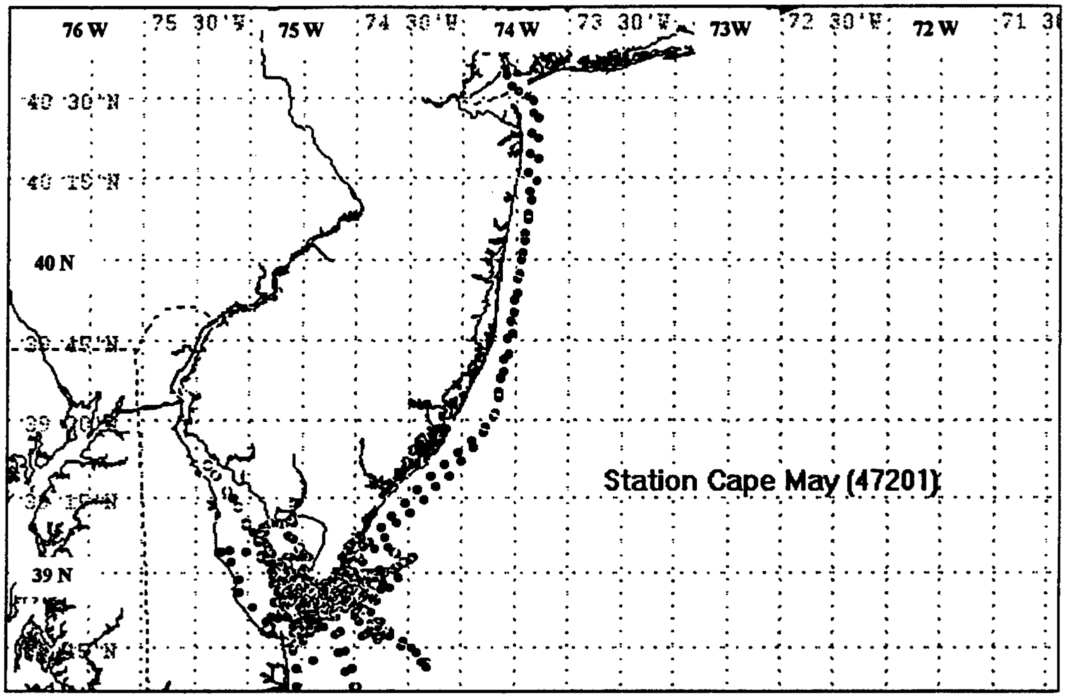


Figure 25 47205 Engine Usage Profile

Station Cape May - 47201 MDR ARO (390 underway hours rcorded)



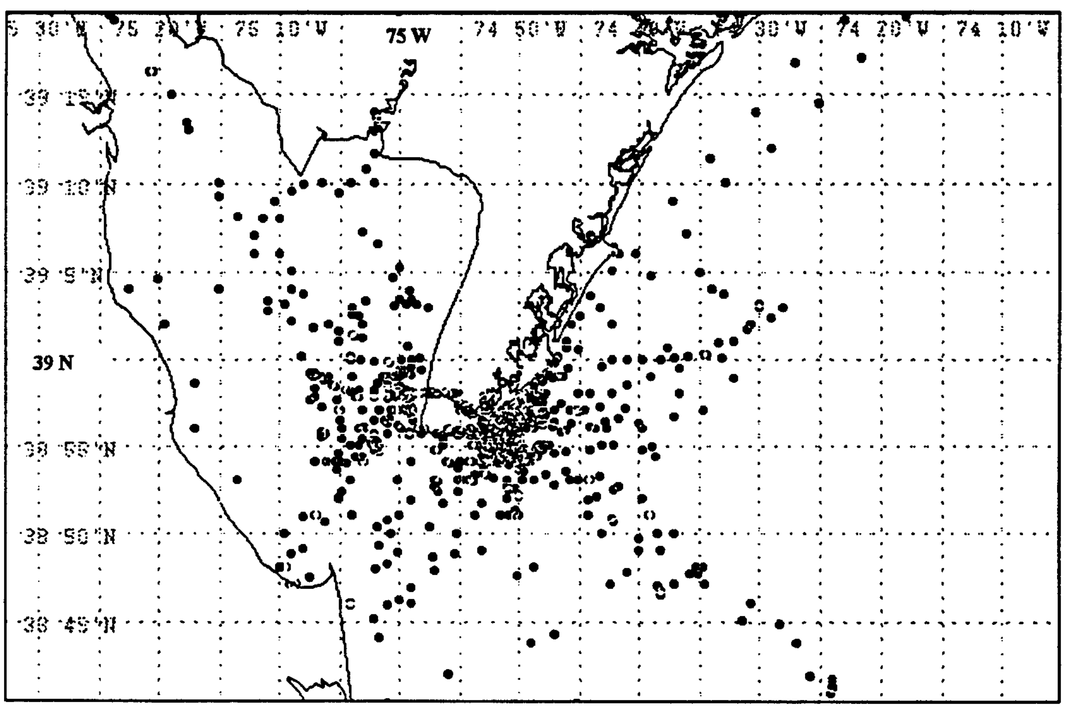


Figure 26 47201 ARO Plot

Station Oregon Inlet - 47202 MDR ARO (291 underway hours recorded)

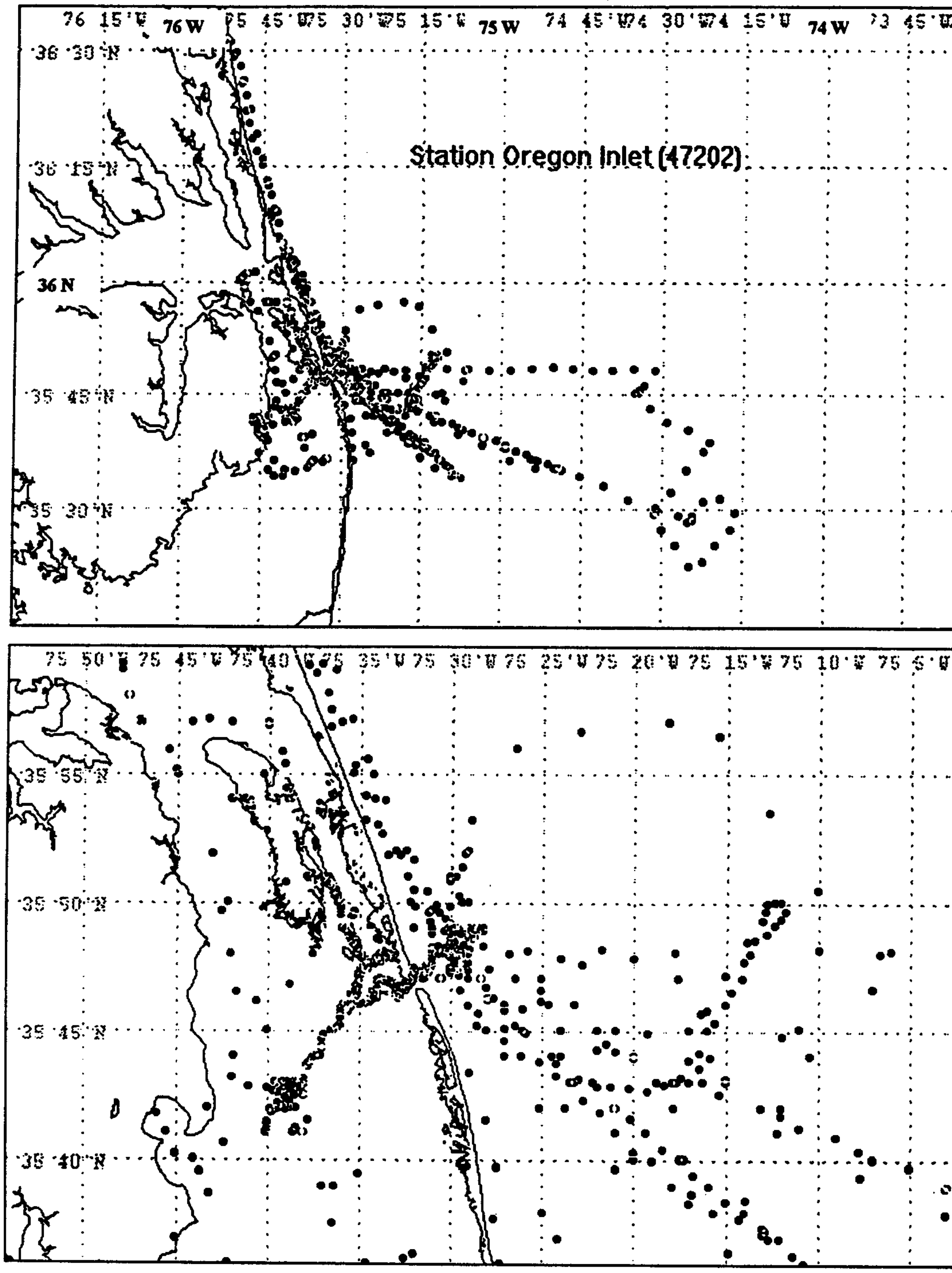


Figure 27 47202 ARO Plot

Station Tillamook - 47203 MDR ARO (272 underway hours recorded)

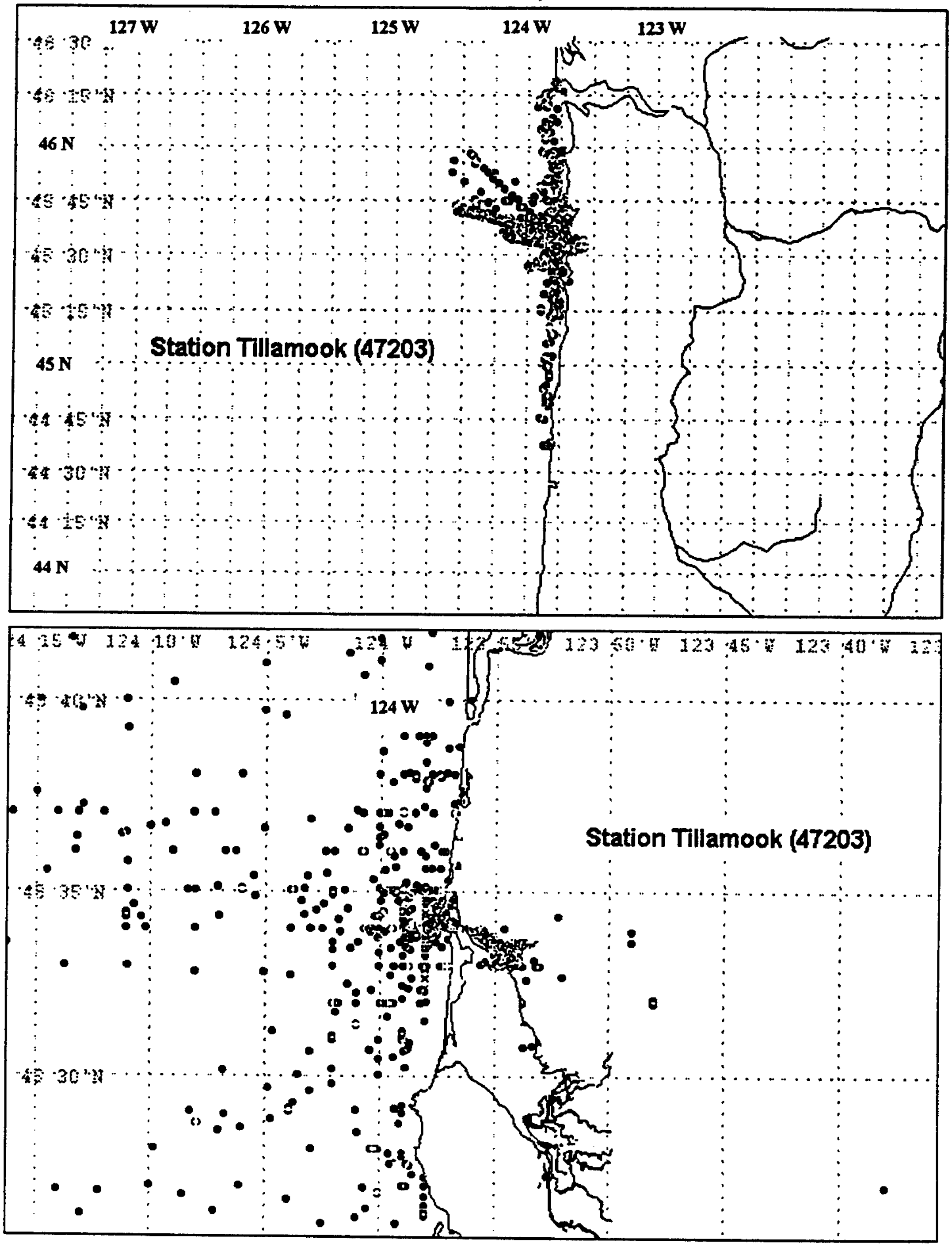


Figure 28 47203 ARO Plot

Station Umpqua River - 47204 MDR ARO (472 underway hours recorded)

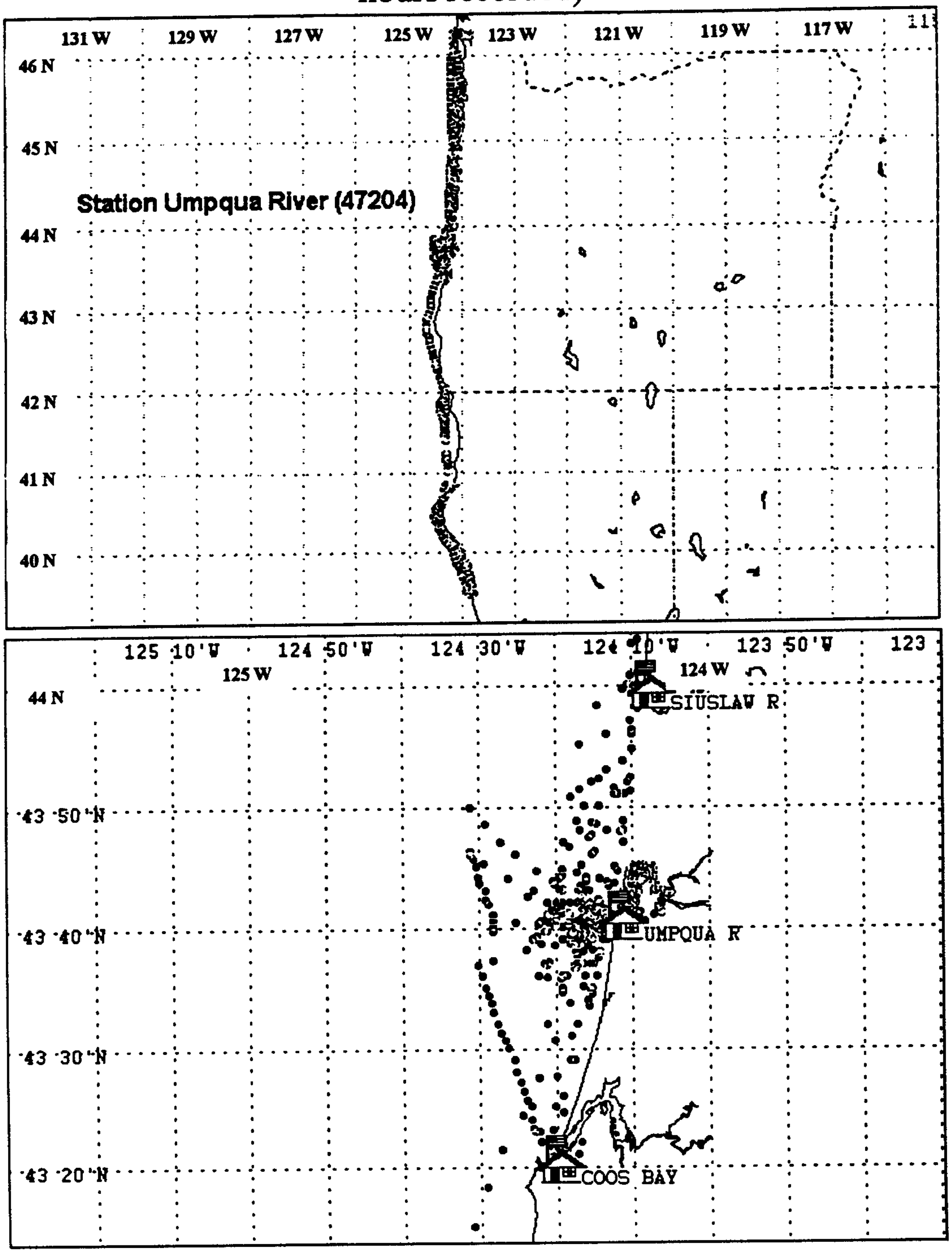


Figure 29 47204 ARO Plot

Station Gloucester - 47205 MDR ARO (644 underway hours recorded)

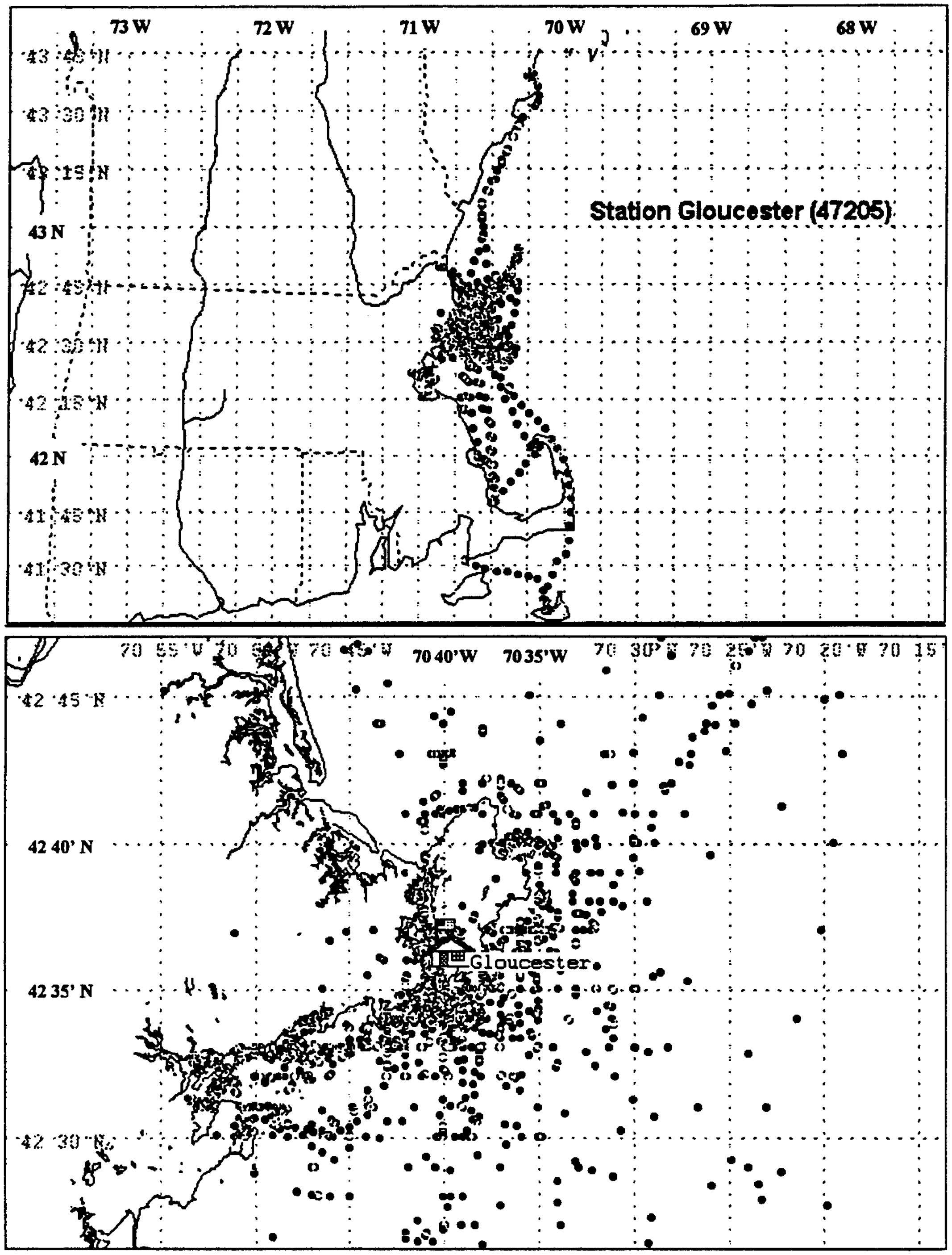


Figure 30 47205 ARO Plot